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Open File Report 87-9

STUDY OF THE NON-METALLURGICAL MARKETS FOR MANGANESE ORE

by

Day & Associates
Leefax Services Limited
The Coopers & Lybrand Consulting Group

Canada-New Brunswick Mineral Development Agreement
Entente Canada-Nouveau-Brunswick L'Exploitation Minerale

Natural Resources and Energy New Brunswick
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STUDY OF THE NON-METALLURGICAL MARKETS

FOR

MANGANESE ORE

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EXECUTIVE SUMMARY

The manganese deposits at Woodstock, New Brunswick consist of low grade manganese carbonate material. The potential attributes of the Woodstock deposits are the location in North America and the possibility that the material will be relatively soluble. The limitations are the low grade, the lack of oxidizing potential of the untreated material and the lack of battery activity.

The potential markets for material from Woodstock, New Brunswick lie in the area of manganese chemicals that may be produced from the manganese carbonate minerals. These include manganese sulphate for the agricultural sector and manganese dioxide. The lack of oxidizing capability or battery activity preclude the use of untreated material in non-metallurgical applications.

This study has focussed on the North American markets for non-metallurgical manganese in various forms, and the means whereby the demand currently is being met, since it was considered that the low grade of the Woodstock manganese deposits could limit its marketability outside North America due to the cost of transportation.

Manganese finds a wide variety of non-metallurgical or non-steel making applications in the form of manganese dioxide, other manganese oxides and manganese chemicals. The uses of manganese metal are relatively minor. Manganese dioxide and other oxides and manganese carbonate occur in

nature and are known as natural manganese ores, as opposed to synthetic manganese dioxides and manufactured manganese chemicals.

The non-metallurgical applications of manganese centre on the oxidizing potential of natural manganese oxide ores and synthetic chemicals, such as potassium permanganate. The number of applications in which the element manganese is of prime importance is relatively limited. This is in direct contrast to steel making which utilizes the specific characteristics of the element manganese in steels.

For most of the non-metallurgical applications of manganese ore, the manganese dioxide or manganese oxide content is of greater importance than the total manganese content. In general, the non-metallurgical applications of manganese, based as they are on the oxidizing potential of the ores, require relatively high grade ores. For many applications, also, the presence of other elements, such as iron, refractories, alkalies and so on, are deleterious. The specifications imposed on manganese ores for non-metallurgical purposes are more exacting and less flexible than those for metallurgical purposes.

The international manganese market is adequately supplied due to the stagnation in demand for manganese in steel making and the ease with which traditional metallurgical ores can be used in non-metallurgical applications. Manganese ore production is being increased in Brazil and Australia and,

potentially, could be increased in other areas to meet both metallurgical and non-metallurgical demand.

In terms of product development, the Woodstock manganese deposits are at a relatively early stage. The range of possible manganese chemicals, including manganese dioxide, that technically could be produced has yet to be established.

The cost of upgrading or processing mineral ores is inversely proportional to the grade of the deposit. The events which could render economic the low grade Woodstock manganese deposits would, undoubtedly, render economic other low grade deposits, including those in the neighbouring state of Maine.

This study concludes that the probability of the Woodstock, New Brunswick manganese deposits finding a market niche during the period up to the year 2000 will be dependent on:

i) the development of an economic process to upgrade the material or to recover manganese in a marketable form;

ii) positive results from a detailed analysis of the market(s) for specific manganese product(s) that could be produced through i), above;

iii) the recognition of the need for a domestic source of manganese to provide security of supply.

INTRODUCTION

Day & Associates, with Leefax Services Limited and The Coopers & Lybrand Consulting Group, has been retained by Supply and Services, Canada, to provide a study of the potential market for non-metallurgical manganese ore from deposits in New Brunswick.

In view of the total reliance of North American consumers on foreign sources of manganese ore, for both metallurgical and non-metallurgical applications, there are grounds for examining the possibilities for a domestic source of production.

The purpose of the study is to review the non-metallurgical markets for manganese and to assess the probability of manganese from the Woodstock, New Brunswick, deposits finding a market niche in the period to the year 2000.

The approach for this study was to draw upon the few sources of reference material on the non-metallurgical manganese industry and to complement this information with a series of interviews with consumers of non-metallurgical manganese in North America.

Principal references were "The Economics of Manganese", published by Roskill Information Services, 1986; "Manganese - The other uses", by Stanley Weiss, 1977; the publications of the United States Bureau of Mines; and the journal, Industrial Minerals. Manganese trade statistics were provided

in publications of The Manganese Centre, Paris, the British Geological Survey and the United States Bureau of Mines. Information on manganese in Canada was provided by the publications of Energy, Mines and Resources, Canada.

With a few notable exceptions, as described in the text of this report, the statistics on the manganese industry refer either to total manganese or to metallurgical manganese: the statistics on non-metallurgical manganese production, trade and consumption are sparse or non-existent.

A series of interviews was conducted with companies and individuals knowledgable of the non-metallurgical manganese market in North America. These interviews provided data that is not available in published form. It was found that information on manganese shipping costs and, particularly, on ocean shipping, was difficult to assemble, although contact was made with those knowledgable of this trade in London and Oslo.

The topic of cost of production has not been addressed in this study. It became clear that the Woodstock manganese deposits would not be marketable as ore but would have to be upgraded and processed on-site. Review of cost of production of existing ore producers, as opposed to producers of manganese chemicals, was believed not to have a significant bearing on the outcome of the study.

It was recognized at the outset that the low grade of the Woodstock manganese deposits could preclude this material

being shipped outside North America. The North American market for manganese of non-metallurgical grade is located principally east of the Mississippi River in the United States, and in Eastern Canada. The focus of the interviews was, therefore, confined to North American markets.

Unless otherwise noted, the units of mass used in this report are metric and the dollar values refer to Canadian dollars.

CURRENT SUPPLY OF MANGANESE ORE

World manganese ore production rose to a peak of 26.43 million tonnes in 1980, representing a 2.8 per cent average annual rate of growth from 21.75 million tonnes in 1973. Since 1980, the world steel industry, which is the chief end-user of manganese, has suffered severe recession, and continued technological advances in steel production have curtailed the demand for manganese ores. World manganese ore production reflected the demand trend with the 1983 level being the lowest in a decade and, despite the small recovery in 1985, total ore production in 1985 was about 8 per cent below the 1980 level.

Manganese is produced by over 30 countries, worldwide, but output is dominated by just seven countries. In decreasing order in 1985, these were the U.S.S.R., South Africa, Brazil, Gabon, Australia, the People's Republic of China and India, as shown in Table I.

PRODUCTION

As noted above, seven countries dominate the manganese-producing industry. In 1985, these accounted for 95.4 per cent of world manganese ore production. The Soviet Union, alone, has accounted for some 40 per cent of world manganese ore output over the last decade. The Eastern European bloc (U.S.S.R., German Democratic Republic, Poland, Czechoslovakia, Hungary, Rumania, Bulgaria) essentially is self-sufficient in manganese, although the ores from the

TABLE I

MANGANESE ORE: SHARE OF WORLD PRODUCTION

(%)

	1973	1980	1985
U.S.S.R.	38.0	37.0	40.5
South Africa	19.2	21.5	14.8
Brazil	7.4	8.6	11.1
Gabon	8.8	8.1	9.6
Australia	7.0	7.6	8.2
China	4.6	6.0	6.5
India	6.8	6.4	4.7
Others	8.2	4.8	4.6
Total	100.0	100.0	100.0

Source: USBM Minerals Yearbooks

U.S.S.R. are of low grade, averaging only 18-25 per cent manganese, and high grade metallurgical ores have been imported from Australia, Brazil and Gabon.

Production in the People's Republic of China is estimated, by the United States Bureau of Mines, to have been static through the 1980's. The country largely is self-sufficient in manganese ores for the steel industry although, due to the low quality of domestic ores, the import requirement is expected to increase in order to provide feedstock for the new Baoshan steelworks.

Western World Producers of Manganese

After the U.S.S.R., South Africa has remained as the second largest producer of manganese ore since the early 1970's, as shown in Table II. Its output consists, primarily, of metallurgical grade ores applicable in the production of manganese ferroalloys. The world recession of 1981-1982 contributed to the halving of South African ore production by 1983. Although recent output has improved, the tonnage achieved in 1985 was still 37 per cent below the 1980 level.

Australia also suffered from the depressed state of the steel industry early in this decade, as over 90 per cent of its output consists of metallurgical grade ores. Like South Africa, Australian ore production fell 44 per cent between 1980 and 1982. There is only one manganese producer in Australia, owned by BHP Mining. The company began to diversify both its product and customer markets through the

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TABLE II

WORLD PRODUCTION OF MANGANESE ORE, 1973-1985

(000t gross weight[1])

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984[P]	1985[E]
Australia[2]	1,522	1,522	1,555	2,154	1,389	1,290	1,724	2,000	1,411	1,123	1,370	1,829	1,989
Brazil[3]	1,615	1,789	2,156	1,696	1,516	1,633	2,259	2,282	2,042	2,341	2,002	2,693	2,700
Bulgaria	38	34	35	40	40	40	42	49	45	45	45	45	45
China	998	998	998	998	998	1,270	1,497	1,597	1,597	1,597	1,597	1,597	1,597
Gabon	1,919	2,064	2,245	2,217	1,851	1,661	2,300	2,146	1,488	1,512	1,857	2,119	2,351
Ghana	318	350	409	312	292	316	272	249	223	160	173	269	307
Hungary[4]	188	134	182	165	120	114	83	83	71	83	59	67	65
India[5]	1,489	1,447	1,557	1,760	1,865	1,567	1,755	1,692	1,526	1,490	1,320	1,081	1,140
Iran	22	30	36	40	40	30	20	20	20	20	20	20	20
Italy	25	14	-	4	9	10	10	9	9	9	7	10	9
Japan	189	167	158	142	126	104	88	80	87	78	75	62	21
Mexico	364	403	428	453	487	523	493	447	578	509	350	476	464
Morocco	146	175	131	117	138	126	135	132	110	96	74	57	44
Philippines	4	1	-	11	21	4	4	1	1	1	-	-	-
South Africa	4,176	4,745	5,769	5,452	5,048	4,317	5,183	5,695	5,039	5,216	2,886	3,049	3,601
Thailand	36	30	25	50	77	72	35	54	11	8	6	9	8
Turkey	3	3	35	34	19	20	42	42	15	7	4	43	50
U.S.S.R.	8,246	8,500	8,459	8,637	8,591	9,057	10,244	9,752	9,154	9,825	9,879	10,070	9,888
Yugoslavia	10	13	17	19	25	27	30	30	31	28	26	27	25
Zaire	334	288	309	182	38	-	-	-	-	-	-	-	-
Others[6]	104	134	129	167	123	73	67	67	68	53	50	54	63
Total	21,746	22,741	24,653	24,650	22,813	22,254	26,283	26,427	23,526	24,211	21,890	23,577	24,387

P: preliminary E: estimated

(1) In addition to the countries listed, Colombia, Cuba and Namibia may have produced manganese ore, but available information is inadequate to make relaible estimates of output.

(2) Metallurgical ore.

(3) Figures are the sum of sales of direct-shipping manganese ore and production of beneficiated ore as reported in Anuario Mineral Brasileiro.

(4) Concentrate.

(5) Much of India's production grades below 35% Mn.

(6) Includes production from Argentina, Bolivia, Chile, Greece, Indonesia, Italy, South Korea, Pakistan, Philippines, Sudan and Zaire.

Source: US Bureau of Mines Minerals Yearbooks.

production of battery grade ores and the signing of large contracts for metallurgical grade ore with the U.S.S.R. and China in 1984. As a result, by 1985, Australian ore production had increased 77 per cent from its 1982 low, virtually regaining the record level achieved in 1980.

An important feature of the manganese ore industry in the last decade has been the rising importance of Brazil as a leading producer. Production of manganese ores in Brazil went from 7.4 per cent of the world total, in 1973, to 11 per cent by 1985. The impressive growth trend is the direct result of a rapidly developing domestic steel industry.

Gabon is the fourth largest producer of manganese ore and its mine, at Moanda, is the world's largest manganese mine. Gabon is also the world's largest producer of natural battery grade ore. Current production of non-metallurgical grades is 60,000-70,000 tonnes per year, or three per cent of Gabon's total production.

India is a large producer of manganese ores but the grade, generally, is low. Exports have been restricted, since 1973, in order to conserve resources and to encourage the domestic ferroalloy industry. In the past, India was an important supplier of chemical grade manganese ore to Europe, but these ores are now consumed internally.

Mexico produces both metallurgical and non-metallurgical manganese ores and is an important export supplier of the non-metallurgical grades.

Ghana was the world's leading supplier of battery grade ore before the 1970's, but, because of declining reserves of high grade oxide ores, its current production of battery grade ore is estimated at about one third (10,000 tonnes) of the 1970 level.

The single Moroccan mine, at Imini, was the only producer, during the 1960's and 1970's, of manganese with ore grades suitable for use in ceramics and chemicals. The reserves, however, rapidly are nearing depletion and total output last year was only one third of the level in 1980.

Currently, about 55 per cent of total world manganese ore production is accounted for by state-owned mines in Gabon, Ghana, India, the U.S.S.R., China, Bulgaria and Hungary. Five companies, GEMCO in Australia, ICOMI in Brazil, Comilog in Gabon and Samancor and Assoman in South Africa, account for about 35 per cent of world production. There is no production of high quality manganese in either Western Europe or North America. These regions are wholly dependent upon imports to satisfy demand from the steel, battery and chemical sectors.

The countries which supply virtually all of the Western World's non-metallurgical manganese ore are Australia, Brazil, Gabon, Ghana, Greece, Indonesia, Mexico, Morocco, South Africa and Thailand.

Brief descriptions of the operations of these countries, with emphasis on the non-metallurgical grades, are given below.

Australia

Groote Eylandt Mining Co. Pty (GEMCO) is a wholly-owned subsidiary of the Broken Hill Pty Co. Ltd. of Australia. The deposit is located less than five kilometers from the Gulf of Carpentaria coast on the island of Groote Eylandt in northern Australia. The ore body is stratiform over an irregular basement, with several areas of battery grade ore within the main deposit.

The mine has been in operation since 1966, mostly supplying the metallurgical market but with smaller quantities of 'premium' ore for the chemical and colouring markets.

Since 1983, a pilot electrolytic manganese dioxide (EMD) plant reportedly has operated intermittently. 1984 saw the first production of battery grade ore, a market which is now being sought aggressively. In 1985, the company announced plans to increase total output from its blending plant by 20 per cent, to 2.4 million tonnes per year. Output of battery grade ore is planned to increase to 30,000 tonnes per year.

Brazil

The major established producer in Brazil is Industria e Comercio de Minerais SA (ICOMI) which is owned by Cia. Auxiliar de Empresas de Mineraçao (CAEMI). The mine at Serra do Navio in Amapa contains approximately twenty small ore bodies along a 12-kilometer belt. Mining is reported to have ceased in 1983, because of large stocks and poor market

conditions. The future of the mine must be considered uncertain in the light of low reserves and the development of the Azul deposit.

The recently developed Azul deposit in Serra de Carajas, northern Brazil, is operated by the State-owned Cia. Vale do Rio Doce (CVRD). The 65 million-tonne deposit lies in a sedimentary basin and is adjacent to two smaller scattered deposits at Sereno and Buriturama. The deposit was discovered in 1971 and the mineral rights acquired by CVRD in 1982. Initial production began on a small scale in 1983 but the completion of a large beneficiation system, in December, 1985, increased total capacity to 1.1 million tonnes per year. 1985 also saw the completion of a 890-kilometer railway to the port of São Luis.

It is proposed to build a plant nearby at Rosario to produce 10,000 tonnes per year EMD and 1,000 tonnes per year potassium permanganate. The US$40 million plant is expected to commence initial production in late 1987. A proposed Soviet-financed ferromanganese plant has met with considerable opposition from independent producers in Brazil.

Gabon

All manganese from Gabon comes from the Moanda mine of Cie. Minière de l'Ogooue (Comilog), a company established in 1953, and which is 36 per cent owned by U.S. Steel, 30 per cent by the Government of Gabon, 3 per cent by Imetal, 18 per

cent by Coframine, 7 per cent by Samal and 6 per cent by Elkem. The mine is located near Franceville with the ore transported 78 kilometers by aerial ropeway and 485 kilometers by rail to Pointe Noire in the Congo. A railway to a new port near Libreville currently is under construction, with completion expected by 1990.

The manganese occurs within five deposits in the Francevillian Basin and has been mined since 1962. Approximately five per cent of the mines' production is used for batteries.

Massive investment is planned for the deposit. The proposed 870-kilometer railway is reported to cost US$2.8 million per kilometer. The new port being constructed at Owendo, near Libreville, designed to accommodate 40,000 dwt vessels with a 15-meter draught, is expected to cost US$263 million. Plans also are in hand for the setting up of a US$300 million ferromanganese industry financed by Gabon (35%), Norway (20%), Belgium (10%), Italy (10%) and Japan (15%).

Ghana

The Nsuta mine in Ghana is operated by the Ghana National Manganese Corporation, formed in 1924 and now owned by the Government of Ghana. The mine is located approximately 62 kilometers from the port of Takoradi. Five deposits are located over a 4-kilometer long, partially dissected ridge.

The mine has been in operation for more than sixty years and, between 1930 and 1970, was the Western World's leading supplier of battery grade ore. However, reserves of the battery grade oxides virtually are exhausted and most of the production is carbonate, which is used for EMD in Japan and Ireland. A US$30 million plant for converting the carbonate ore into manganese dioxide was completed in 1983. However, the 1,100 - 1,500 tonnes per day plant is not believed to be in operation yet, due to power shortages and transport problems. The company recently received US$6 million in loans from the European Investment Bank in Luxemburg to rehabilitate the washing plant and purchase new equipment. In addition, the past two years have seen improvements in rail links to Takoradi, financed by the World Bank. Exploration work to expand reserves is being undertaken with the help of Rumanian geologists.

Greece

Manganese ore production in Greece comes from two companies. C. Christoforidis Mining SA (owned and managed by Constantin Christoforidis) operates the Neohorton mine in Hellindikis. Formerly operated by Elbaumin, the other Greek producer, capacity has been expanded since 1985, but remains relatively low. It is hoped to install a heavy media separation plant to upgrade battery grade ore from 72 to 75 per cent manganese dioxide. European markets are being sought for the product.

Eleusis Bauxite Mines (Elbaumin), owned by Hellenic Industrial and Mining Investment Co., has manganese mines in the Neurokopi area in northern Greece. Current production is believed to be from the mine at Drama. Elsewhere in Greece, EMD is produced by Tekkosha Hellas ABE, which is 65 per cent owned by Toyo Soda Manufacturing Co. Ltd.

Indonesia

Indonesia produces high grade manganese ores for battery applications, some of which is consumed domestically in a dry battery plant operated by a Union Carbide subsidiary.

Production comes from Java, Flores Island, Duo Island and, since 1980, from the Bima area of the West Nusa Tenggara islands.

Exports are made principally to Japan.

Mexico

The largest producer of ore in Mexico is Cia. Minera Autlan SA de CV. The company produces battery grade ore from the Nonoalco mine and 'metallurgical grade' ore from the Tezintla mine. Both mines are located in Hidalgo State. Battery ore is surface mined from beds 30 meters thick, dipping 20-30°, whilst the 'metallurgical ores' have been produced by surface mining since 1969, and underground mining since 1978. There are at least three other manganese deposits in the immediate vicinity of Tezintla. The metallurgical grade carbonates are used in a variety of non-metallurgical applications, including EMD which has been produced on a

small scale since 1984. It is proposed to construct a 6,000 tonnes per year EMD plant in the near future. Plans also have been announced to start production of manganese sulphate in the second half of 1987. Industrias Sulfamex SA de CV, an affiliated company of Minera Autlan, plans the US$8 million plant at Tamos, Veracruz. The first phase is expected to have a capacity of 20,000 tonnes per year with a possible second phase producing 36,000 tonnes per year. These expansion plans for some products are in marked contrast to the decline in battery grade production, due to excess inventory in the past few years.

Other smaller producers of battery ore in Mexico include Cia. Minera Buena Vista SA and Cia. Minera San Martin y Anexas.

Morocco

The Imini mine in Morocco is operated by Sté. Cherifienne d'Etudes Minières (SACEM) which is owned by Imetal (50.33%) and the Bureau de Recherches et de Participations Minières (42.99%). Located in central Morocco, the manganese occurs in three beds, 1.3 meters thick, 160-400 meters wide and up to 20 kilometers long. Production of non-metallurgical grades commenced in the 1960's, and these grades now represent all the production. However, output has declined dramatically since 1980, due to declining reserves. The mine now concentrates on ultrafine grades which are a high value export commodity. Existing reserves are believed

to be sufficient for about five years' production but exploration is being undertaken to find additional reserves along the main trend of mineralization. The likelihood of success cannot be predicted.

South Africa

South African production of non-metallurgical manganese comes from three main sources:

a) Rand London Manganese Mines (Pty) Ltd.

b) Samancor .

c) Transwest Mineral Co. (Pty) Ltd.

Most non-metallurgical manganese in South Africa is produced by Rand London Manganese Mines, which is managed and 40 per cent owned by Metorex and 60 per cent owned by Rand London Corp. The company mostly supplies the uranium industry from surface mines at Randfontein, Elandsfontein and Ryedale. Small quantities of ore also are sold for batteries. The company does not export any of its products.

Samancor, the largest producer of metallurgical manganese in South Africa, is 50 per cent owned by Gencor (General Mining Union Corp. Ltd.) and 30 per cent owned by Anglo American Corp. of South Africa Ltd. It has surface mines at Manatwan and Hotazel and an underground mine at Wessels producing ore for uranium processing and EMD production.

The only South African company which is exporting and expanding operations at the present time is Transwest

Minerals Co. (Pty) Ltd. (incorporating Klipveld Manganese (Pty) Ltd.) The company's surface mine at Lichtenburg supplies ore for uranium processing, ceramics, bricks and batteries. The first stage of its expansion program has improved material handling and preparation, the second stage, now under way, involves improvements in processing.

Thailand

Thailand produces both metallurgical grade ores, which are now relatively unimportant, and battery grade ores, the output of which has remained steady over the past decade. A negligible quantity of chemical grade ore is produced.

Manganese ore is mined in approximately ten mines, with the battery grade ore from Lampoon and Loei provinces.

Output is consumed entirely domestically.

Table III shows the major producers of non-metallurgical manganese and the principal end-use sectors of output.

Capacity

Due to the complexity of the manganese ore market, and the fact that there is considerable interchangeability in the use of ores in both metallurgical and non-metallurgical end uses, it is virtually impossible to assign non-metallurgical ore capacity figures to each producer.

Table IV shows reported total manganese ore production capacities for the major producers of non-metallurgical manganese.

TABLE III

MAJOR PRODUCERS OF NON-METALLURGICAL MANGANESE ORE BY END USE SECTOR

Producer	Battery	EMD	Pigment	Ferrite	Flux	Chemicals	Uranium	Zinc
Australia	x		x	x	x	x	x	x
Brazil	x	x	x			x	x	
Gabon	x	x			x	x		x
Ghana		x						
Greece	x							
Mexico	x	x				x		
Morocco			x	x	x	x		x
South Africa							x	

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TABLE IV

MANGANESE ORE PRODUCTION CAPACITY

Country	Mining Company	Production Capacity (ore tonnes per year)
Australia	Groote Eylandt Mining Co. Pty Ltd.	2 million
Brazil	CVRD	1 million
	Industria e Commercio de Minerio SA (ICOMI)	1.6 million
Gabon	Compagnie Minière de l'Ogooue (COMILOG)	3 million
Ghana	Ghana National Manganese Corp.	300,000
Greece	Eleusis Bauxite Mines (Elbaumin)	12,000
	C. Christoforidis Mining SA	130,000[1]
Mexico	Cia. Minera de Autlan SA de CV	600,000
Morocco	Sté. Cherifienne d'Etudes Minières (SACEM)	50,000
South Africa	Samancor	5 million
	Rand London Manganese Mines (Pty) Ltd.	300,000
	Klipveld Manganese (Pty) Ltd.	18,000-36,000

[1] Planned capacity.

The countries for which such information is more meaningful are those whose output is entirely or largely of non-metallurgical grades, Morocco and Greece.

In general, the supply capability of the producers of manganese ore used in non-metallurgical applications appears adequate for a number of reasons:

- the downturn in demand for manganese in the steel industry has generated surplus capacity for the metallurgical grades;
- manganese ores that are classified as metallurgical grades, generally or by the producers, are used in non-metallurgical applications;
- a number of expansions to production have taken place, in Australia and Brazil, among others, which will supply non-metallurgical grades.

The amount of direct shipping manganese ore now is relatively low and in some cases it is possible that production of non-metallurgical grades could be accomplished by using plant capacity previously dedicated for metallurgical grades, In that case, non-metallurgical ore capacity could be expanded at small cost relatively rapidly.

Annual Production Rates

In regard to capacity or supply capability, it is perhaps as useful to review figures relating to production of the non-metallurgical, i.e. non-steel making, grades, where available, and these are discussed below.

As noted in an earlier section, production rates for different grades of manganese ore are seldom reported consistently. Table V summarizes the latest available production figures for the producers of non-metallurgical manganese

TABLE V

ANNUAL MANGANESE PRODUCTION

Country	Mining Company	Total Production[1]	Non-Metallurgical Production
		(tonnes ore per year)	
Australia	Groote Eylandt Mining Co. Pty Ltd.	1,828,717 (1984)	150-200,000
Brazil	CVRD	157,300 (1985)	40,000
	Industria e Commercio de Minerio SA	2,300,000 (1985)	c 15,000
Gabon	Cie. Minière de l'Ogooue	2,223,500 (1985)	160-170,000
Ghana	Ghana National Manganese Corp.	357,270 (1985)	
Greece	Eleusis Bauxite Mines		
	C. Christoforidis Mining SA	c 9,000	c 9,000
Mexico	Cia. Minera de Autlan SA de CV		
Morocco	Sté. Cherifienne d'Etudes Minières	44,000 (1985)	c 44,000 (1985)
South Africa	Rand London Manganese Mines (Pty) Ltd.	c 220,000	c 200,000

c : circa
1 : Metallurgical plus non-metallurgical

including, where possible, the figures for non-metallurgical material alone.

Non-Metallurgical Grades

Four companies dominate the supply of non-metallurgical grades of manganese ore:

Groote Eylandt Mining Co., Australia
Comilog, Gabon
Rand London Manganese, South Africa
Ste. Cherifienne d'Etudes Minieres, Morocco.

With the exception of Morocco, each of these has production capabiity of over 100,000 tonnes per year of non-metallurgical manganese. Moroccan output has declined from over 100,000 tonnes per year prior to 1982 to 44,000 tonnes in 1985. Over the short term, however, Morocco will remain a major individual producer of non-metallurgical manganese.

Although South Africa is a significant producer of non-metallurgical manganese, most of its production is consumed domestically.

Other producers, with output of less than 50,000 tonnes per year of non-metallurgical manganese are:

Cia. Vale do Rio Doce (CVRD), Brazil
Ghana National Manganese Corp., Ghana
Cia. Minera de Autlan SA de CV, Mexico

CVRD is the largest in this group, followed by Mexico, both with present production capability in the range of 35,000 tonnes per year of non-metallurgical manganese. Ghana was an important supplier of battery grade manganese between 1930 and 1970 with output of some 30,000 tonnes per year.

with a further 10,000 tonnes per year of fines for use in other non-metallurgical sectors. Output now is around 10,000 tonnes per year of battery grade ore.

Production by the older Brazilian producer, Industria e Commercio de Minerio SA (ICOMI), ceased in 1983, reportedly due to poor market conditions and high inventories. Output was of the order of 16,000 to 20,000 tonnes per year of non-metallurgical ore (around one per cent of total production). Shipments continued in 1984.

India produces a large quantity of manganese ore that no longer enters international trade.

The remaining, smaller, producers of non-metallurgical manganese are:

Eleusis Bauxite Mines (Elbaumin), Greece;
C. Christoforidis Mining SA, Greece; and
operations in Indonesia and Thailand.

These are important to domestic production of batteries in Indonesia and Thailand, and supply minor quantities of ore to Japan. In Greece, an EMD plant owned by a subsidiary of one of the Japanese EMD producers, takes a significant proportion of total ore production.

Japan also has production of non-metallurgical manganese that is used domestically and, indeed, these domestic carbonate ores were the basis, originally, for the preference for carbonate ores for EMD manufacture.

Magnitude of Reserves

Table VI summarizes the available data on ore reserves of the producers of non-metallurgical manganese.

In general, however, estimates of non-metallurgical reserve life are of limited usefulness since, in many cases, ore for different purposes is grouped within overall figures. Additional difficulties are caused by the tendency to combine proven, probable and possible reserves in published figures.

The countries for which reserves of non-metallurgical grade ore are approaching exhaustion are Morocco and Ghana.

Through the 1960's and 1970's, Morocco was the only producer of a range of ore grades that were used exclusively in chemical and ceramic applications. Production of metallurgical ores decreased through the 1970's and has now ceased. Total output peaked in 1974 at 175,000 tonnes. Since 1982, output has declined each year, to reach 44,000 tonnes in 1985 and it is anticipated that the existing reserves of high grade non-metallurgical ores will not support production for more than five years.

Between 1930 and 1970, Ghana was the western world's largest supplier of battery grade manganese ore based on high grade oxide reserves. These reserves are now low and output of battery grade is only around 10,000 tonnes per year. In 1983, a new nodulizing plant to convert carbonate ore to battery grade manganese dioxide was constructed. A pilot plant is planned to upgrade the low quality ores in the

TABLE VI

ORE RESERVES OF MAJOR PRODUCERS

Country	Mining Company	Reserves	Grade
Australia	Groote Eylandt Mining Co. Pty Ltd.	160 M t proven 600,000 t battery g. proven	46% Mn
Brazil	CVRD	65 Mt; inc. 12 Mt battery g.	43% Mn
	Industria e Commercio de Minerio SA	20 Mt	41-49% Mn
Gabon	Cia. Minière de l'Ogooue	230 Mt	50% Mn
Ghana	Ghana National Manganese Corp.	30 Mt carb. ore	31% Mn
Greece	Eleusis Bauxite Mines	1 Mt	30-45% Mn
	C. Christoforidis Mining SA		72% MnO_2 32% Mn carb. ore
Mexico	Cia. Minera de Autlan SA de CV	1.5 Bt, 29 Mt carb. ore	29% Mn
Morocco	Sté. Cherifienne d'Etudes Minières	Close to exhaustion	41-93% MnO_2
South Africa	Rand London Manganese Mines (Pty) Ltd.	N/A	35% MnO_2
	Klipveld Manganese (Pty) Ltd.	N/A	33-70% MnO_2

Nsuta-Wassaur area. Ghana National Manganese Corp. has received financial assistance for exploration for additional reserves and, in the west of the country, a Rumanian company is undertaking exploration.

Among other producers, the reserve position appears, generally, to be good.

Groote Eylandt Mining Co. in Australia reports proven reserves of 600,000 tonnes of battery grade ore, with 2 million tones inferred reserves. Production of battery grade ore is currently about 15,000 tonnes per year, with a planned increase to 30,000 tonnes per year.

CVRD of Brazil, the second relatively new producer of battery grade ore, reports 12 million tonnes of battery ore.

For other non-metallurgical applications, metallurgical grades are used, for example in the production of EMD in the United States, or can be upgraded to meet the more exacting requirements of the non-metallurgical sectors.

The supply of so-called metallurgical ore upgraded to meet non-metallurgical specifications would be sufficient to meet world demand for many centuries. Since non-metallurgical applications represent only some 5 per cent of total consumption, the upgrading of metallurgical ore to non-metallurgical grades could be achieved without significant adverse effect on metallurgical ore supply.

Estimated Cost of Delivery to Market

Generally speaking, movements of large tonnages of manganese ores from the producing countries to markets are made by means of ocean-going bulk carriers. As with other sectors in international shipping, there has been a significant over capacity of available tonnage to meet the requirements of the dry cargo market. Rates as of mid-1986 were, in real terms, probably at their lowest levels ever, having declined by about 40 per cent from the already severely depressed rates encountered at the beginning of the year. In the first half of 1986, nearly 4 million tons of large dry cargo-carrying vessels were removed from the market.

In addition, vessels continue to trade incurring losses that well exceed lay-up costs. This is probably due partly to the optimism of their owners, but is also due to the demands of the financiers of these vessels. Typical six-month time charter rates for 30,000 dead weight tons (dwt) economical bulk carriers, as of June, 1986, were only US$3,200 per day, while, for Panamax size vessels (60,000 dwt), charter hires were only some US$4,000 per day. These rates may be compared with rates in January, 1986, of US$4,500 per day for 30,000 dwt bulk carriers and up to US$6,000 per day for Panamax size vessels.

Ocean freight rates for movements of bulk commodities have been depressed over the past five years. Manganese freight rates, as with other bulk cargoes, are influenced by the

general state of the bulk carrier market, the size of the shipment to be made - hence the size of the vessel to lift the cargo - and the distance over which the cargo is to be moved.

No significant increase in dry cargo rates is projected by recognized shipping authorities in the near future. Thus, no significant changes are anticipated to occur in the well established patterns of the ocean movement of manganese ore cargoes from producers to their traditional markets.

Typical rates from South Africa, Morocco and Australia to North America have ranged between US$6 and US$9 per short ton. These rates apply to handy size vessels (15,000-25,000 dwt), the size range of vessels utilized in the manganese trade. These rates reflect an ocean transportation cost from US¢0.3 to US¢0.45 per pound. Compared with the prices for metallurgical grade fines in the United States from Australia, estimated in 1987 to be about US¢4.4 per pound, ocean transportation costs represent approximately 10 per cent of the delivered cost of the ore.

The cost of finished products, such as Japanese-produced EMD or United States-produced potassium permanganate, can reach US$1-1.5 per pound. It is estimated that the transportation costs of the raw material is less than 0.5 per cent of the price of finished product.

Since there is no manganese mined in Canada or the United States, ore is imported into North America utilizing bulk

carriers. The principal ports of entry are Montreal and United States east coast ports, such as Norfolk, Baltimore, Philadelphia range and New Orleans. The exception is the small volume of relatively high value manganese compounds imported principally from Mexico.

PRODUCT SPECIFICATIONS

Terminology Applied to Manganese Ores

Table VII lists the principal manganese ore minerals, with their chemical formulae and manganese content. The highest grade manganese ores are those containing a high proportion of the dioxide minerals, of which pyrolusite is one of the most common. Rhodochrosite is the most common of the carbonate ore minerals and braunite is the only manganese silicate ore mineral.

Although the terms 'metallurgical', 'battery' and 'chemical' tend to be applied to manganese ores, these do not adequately describe either the ores themselves or the end use of any particular ore.

Manganese ore for metallurgical purposes (primarily for steel production) is purchased on the basis of manganese content - hence, the classification into high/low grade ore, ferruginous manganese ore and manganiferous iron ore.

There are no standard industry classifications for manganese ores, whether for metallurgical or non-metallurgical end uses. Three countries have established broad

TABLE VII

FORMULAE AND MANGANESE CONTENT OF PRINCIPAL MANGANESE MINERALS

Mineral	Formula	Mn (%)
Pyrolusite	MnO_2	63.2
Ramsdellite	MnO_2	63
Polianite	MnO_2	N/A
Manganite	$Mn_2O_3H_2O$	62
Cryptomelane	KMn_8O_{16}	45-60
Psilomelane	$BaMn_9O_{18}2H_2O$	N/A
Hausmannite	$MnMn_2O_4$	72
Braunite	$3Mn_2O_3MnSiO_3$	50-60
Bixbyite	$(Mn, Fe)_2O_3$	30-40
Jacobsite	$MnFe_2O_4$	24
Hollandite	$BaMn_8O_{16}$	N/A
Coronadite	$PbMn_8O_{16}$	N/A
Rhodochrosite	$MnCO_3$	48
Rhodonite	$MnSiO_3$	42
Alabandite	MnS	N/A

Source: Economics of Manganese, 1986.

classification systems, depending upon their particular interests.

The United States government developed specifications for its National Defense Stockpile requirements and the Bureau of Mines has applied broad terms for its compilation of statistics. Japan, as the largest importer of manganese ores, recognizes four categories, depending on end use. South Africa, as the largest exporter of manganese ores (though not of non-metallurgical grades), has three categories.

Table VIII summarizes the classifications used by these three countries and Table IX outlines the National Defense Stockpile requirements. Both tables, however, provide only the broadest guide to the specifications required in the non-metallurgical end uses.

Virtually all of the oxide ores used for both metallurgical and non-metallurgical applications contain a minimum of 47 per cent Mn and, for production of soft ferrites, for example, 60 per cent Mn may be required. The carbonate ores contain 40 to 45 per cent Mn but are more easily converted to EMD by acid attack than are the oxide ores which first have to be reduced to MnO (manganous oxide).

Manganese ore for non-metallurgical purposes is assessed and purchased on the basis of the physical and chemical properties of the ore, as well as on the manganese content. The physical and chemical properties of manganese ores for non-metallurgical purposes include:

TABLE VIII

SUMMARY OF MANGANESE ORE CLASSIFICATIONS OF THE UNITED STATES, JAPAN AND SOUTH AFRICA

United States	Bureau of Mines		
	Manganese ore	>35% Mn	
	Ferruginous manganese ore	>10%	35% Mn
	Manganiferous iron ore	>5%	10% Mn
Japan	High grade manganese ore	>39% Mn (for Mn alloy)	
	Low grade manganese ore	>39% Mn (for electrolytic Mn, Mn metal, alloys)	
	Ferruginous manganese ores	(for hot metal additions)	
South Africa	Metallurgical grade ore	>35% Mn:	48% Mn
			45-48% Mn
			40-45% Mn
			30-40% Mn
	Chemical grade ore	>35% MnO_2:	35-65% MnO_2
		>35% MnO_2	
	Manganiferous ore	>5% Mn+Fe	15-30% Mn

Source: Economics of Manganese, 1986.
Kirk-Othmer, Encyclopedia of Chemical Technology.

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TABLE IX

UNITED STATES NATIONAL DEFENSE STOCKPILE

SPECIFICATIONS OF METALLURGICAL AND CHEMICAL GRADE ORES

Metallurgical Grade	%
Mn, min	48
Fe, max	6
Al_2O_3, max	7
$Al_2O_3 + SiO_2$, max	11
As, max	0.18
P, max	0.19
Cu + Pb + Zn, max	0.30

Chemical Grade	Type A (%)	Type B (%)
MnO_2, min	80.0	82.0
Mn, min		53.0
Fe, max	3.0	3.0
Al_2O_3, max		3.0
P, max		0.20
As, max		0.10

Type: Type A; satisfactory for use as oxidizing agent in e.g., manufacture of hydroquinone.

Type B; satisfactory for manufacture of permanganate.

Source: Kirk-Othmer Encyclopedia of Chemical Technology.

manganese dioxide content
availability of oxygen
grinding characteristics
shape and specific area of manganese particles
trace and heavy metal content

In particular, the suitability of manganese ores for batteries is more dependent on crystal structure, surface area, pore size distribution, particle shape and size, electrical conductivity, surface conditions, chemical composition, impurities and structural defects than on manganese dioxide content alone.

Manganese ores for chemical applications can vary widely in specifications, depending upon the particular requirements of the consumer and significant quantities of so-called 'metallurgical ores' are used in non-metallurgical applications. In the production of many manganese chemicals, the oxygen content is important, but few ores are produced specifically on that basis.

Metallurgical Grades

In its metallurgical applications, manganese is used mostly in the intermediate ferroalloy forms of ferromanganese, silicomanganese and ferromanganese silicon. Ores or blends for ferroalloy production should have a manganese content of 35-55 per cent, manganese to iron ratio of 7.5 to 1 and phosphorous content not exceeding 0.2 per cent. A manganese content of 48 per cent is taken as the pricing standard. (The National Defense Stockpile specifications are

shown in Table IX).

Table X shows typical metallurgical ores currently exported to Japan from major suppliers.

Non-Metallurgical Grades

Table XI provides a summary of analyses of manganese ores imported into the United States from seven sources for non-metallurgical and chemical applications. The data were compiled in the mid-1970's but illustrate several important points:

- the manganese content is generally over 50 per cent;
- the manganese dioxide content is specified and ranges from 71 per cent to over 85 per cent;
- the manganous oxide content is also specified;
- carbonate ores (examples 6 and 7) contain over 30 per cent Mn;
- the iron content is relatively low;
- refractory elements, alkali metals and heavy metals are specified.

Tables XII to XX show typical specifications of manganese ores for a variety of end-use applications. These confirm the observations noted above and show also that for some applications the content of heavy metal and trace elements is important.

Tables XII to XX have been compiled from suppliers' data and do not contain reference to maximum or minimum specifications that would be required by consumers or customers. Generally, customers will specify the minimum acceptable

TABLE X

METALLURGICAL MANGANESE ORES - TYPICAL SPECIFICATIONS

	Mn	MnO	Fe	Fe_2O_3	SiO_2	Al_2O_3	CaO+MgO	P
Cia. Minera Autlan								
Nodule	38		10		17	[5]		0.1
ROM	27-28		5- 6		(10-13[1])		5- 5.6	
COMILOG								
Lumpy	50-52		2.5- 3.5		12.5- 3	6- 8		0.11-0.13
High grade fines	49-50		3- 4		2- 4	6- 7		.105-.125
ICOMI								
Lumpy	48		6.5		3.5	6.5		.15
Pellet	54		6.5		3.5	6.5		.15
Fines	48-48.5		5.5-6.9		2-3	5/5-6/3		.08-.1
CVRD								
Lumpy	45.5		3.5		2.7	9.8		.07
Sinter	43		4.7		3.5	10.8		0.07
ASSOMAN								
Lumpy-super high grade	50-52		10-12		3.5	.3-.6		.04
High grade	58-50		11-13		4- 5	.3-.5		.04
Low grade	34-36		21-23		4.5-5.5	4- 7		.05
High ferrous grade	38-40		18-20		5- 6	.3-.6		.05
Fines-high grade	47-49		12-14		4- 6	.3-.5		.04
High ferrous grade	36-39		19-22		5- 7	.3-.5		.05
SAMANCOR								
Wessels lumpy	46-48		15		6	4		.05
Mamatwan lumpy	40-38		6		6		[2]	.05
Mamatwan fines	40-37		7		7		[2]	.05
MIDDELPLAATS								
Met. lumpy	37-40		6		([1])			.05
Met. fines	37-40		6		([1])			.05
Fe-Mn ore lumpy	30		4		([1])			.05

1. SiO_2 + Al_2O_3
2. CaO^2

Source: The Tex Report, Ferroalloys, 1986.

TABLE XI

ANALYSES OF MANGANESE ORES* USED IN NON-METALLURGICAL APPLICATIONS OR MANUFACTURE OF Mn CHEMICALS, Wt%

Contituent	1	2	3	4	5	6	7
Mn (total)	55.42	54.85	51.4	52.30	48.85	30.81	30-35
MnO_2	85.9	83.64	74.0	78.30	70.99	nil	
MnO	1.51	3.04	5.99	3.62	5.16	39.77	
Fe (total)	0.53					1.04	2-3
Fe_2O_3	0.76	2.64	3.16	3.13	7.55		
S	0.012	0.101		0.006		0.04	
P	0.039	0.08	0.140	0.095	0.081	0.06	
Cu	0.21	0.03	0.05	0.0089	0.036	trace	
Pb	0.98		0.02	0.025	0.025	trace	0.1-0.2
Co		0.095	0.01	0.0193	0.054		0.1
Ni		0.05	0.07	0.0210	0.092		0.1
SiO_2	4.28	1.06	3.81	2.62	2.93	12.68	15-20
Al_2O_3	0.86	4.67	5.42	3.00	4.52	2.15	
CaO + MgO	0.78	0.05	0.1	0.105	0.08	8.25	
BaO	2.37	0.37	0.15	2.34	0.28	trace	
$K_2O + Na_2O$	0.42	0.61	1.66	0.89	1.89	0.175	
CO_2		0.41		0.33	0.67	33.68	

* 1, Imini mine, Morocco; 2, Moanda mine, Gabon; 3, Kisenge, Zaire; 4, Groote Eylandt, Australia; 5, Amapa, Brazil; 6, Ghana (N-grade carbonate); 7, Japan (high-grade carbonate).

Source: Kirk-Othmer Encyclopedia of Chemical Technology.

TABLE XII

NON-METALLURGICAL ORE - BATTERY GRADES

	Groote Eylandt %	Elbaumin Scalma 74 %	Elbaumin Scalma 72 %
Mn	53.7	49.00	48.00
MnO_2	80.5	74.00	72.00
Fe	2.23	2.00	2.5
Al_2O_3	2.44	-	-
SiO_2	2.18	8.5	8.5
BaO	1.56	-	-
CaO	0.08	3.5	4
K_2O	0.66	-	-
MgO	0.69	-	-
TiO_2	0.13	-	-
ZnO	0.02		
Zn		1.0	1.2
	ppm		
Cu	121	0.04	0.05
Ni	244	-	-
Co	126	-	-
Cr	7	-	-
Pb	35	0.8	1.3
As	30	-	-
Sb	20	-	-
BET surface area	27 m^2/g	-	-
pH in water	7.2	-	-
pH in electrolyte	6.2	-	-
Free water	0.03	-	-
Combined H_2O	5.08	-	-
Insolubles	-	10	10.5

Source: Industrial Minerals, 1985.
Economics of Manganese, 1986.

TABLE XIII

NON-METALLURGICAL ORE - EMD GRADES

	Imini 80%	Comilog*
MnO_2	79.18	-
MnO	3.25	-
Mn	-	53.00
Fe	-	2.04
Fe_2O_3	0.69	-
Al_2O_3	1.47	5.34
SiO_2	6.41	1.4
BaO	3.35	-
CaO	0.41	0.1-0.2
K_2O	0.83	.7-.8
Na_2O	0.07	0.07-0.2
MgO	0.34	.07-.17
TiO_2	0.05	-
ZnO	0.03	-
SO_3	0.015	-
P_2O_3	0.085	-
CuO	0.21	-
NiO	0.018	-
CaO	0.037	-
PbO	1.63	-
As	0.036	-
Sb	-	.001-.002
Mo	-	.002-.005
CO_2	0.45	-
H_2O	1.47	7.00

* Comilog: Typical analysis supplied to Kerr-McGee

Source: Industrial Minerals, July, 1985.
Assignment interviews.

TABLE XIV

NON-METALLURGICAL MANGANESE ORE - BRICK PIGMENT GRADES

	Mangalox K	Bricolor X45	Bricolor C45	Bricolor H45
MnO_2	-	68	76	80
MnO	-	5	2	2
Mn_3O_4	69	-	-	-
SiO_2	7	3.5	8	8
Al_2O_3	0.5	7.5	3	2
Fe_2O_3	-	10	2	1
FeO	15			
TiO_2	-			
CaO	4			
MgO	0.5			
BaO	0.5			
Na_2O	0.2			
K_2O	0.2			
PbO	-			
SO_3	-			
S	0.05			
P_2O_5	-			
P	0.04			
NiO	-			
CoO	-			
CuO	-			
ZnO	-			
Co_2	0.8			
Water of cryst.	-	2.5	1.5	1.5
L.o.i.	2			

Source: Industrial Minerals, July, 1985; Jan de Poorter products.

TABLE XV

NON-METALLURGICAL MANGANESE ORE - FERTILIZER INDUSTRY GRADE

	Comilog "Flue Dust" %
Mn	32-34
SiO_2	7-11
Al_2O_3	8-12
Fe	6
CaO	3.5-4.5
MgO	1-1.5
BaO	0.2-0.4
C	7-13
Alkalies	2.3-3
Moisture	10-15

Size: 99% -500 microns

Source: Weiss, 1977.

TABLE XVI

NON-METALLURGICAL MANGANESE ORE - CHEMICAL AND OXIDIZING AGENT GRADES

	Jan de Poorter		Imini	Imini
	Mangalox J	Mangalox A	UF84	UF80
MnO_2	89	79	84.22	80.41
MnO	1.5	1	1.16	1.39
SiO_2	0.5	3.5	4.25	5.58
Al_2O_3	0.8	4.5	1.31	1.8
Fe_2O_3	1.5	3	0.86	0.53
TiO_2	0.05	0.3	0.05	0.07
CaO	0.9	0.05	1.99	2.35
MgO	0.02	0.35	1.17	1.41
BaO	2.9	2.8	0.41	0.7
Na_2O	-	0.1	0.03	0.03
K_2O	0.2	0.6	0.33	0.47
PbO	0.07	0.02	0.26	0.47
SO_3	0.8	-	0.055	0.045
S	-	0.01	-	-
P_2O_5	0.2	-	0.147	0.082
P	-	0.09	-	-
NiO	0.02	0.05	0.009	0.01
CoO	0.01	0.04	0.018	0.019
CuO	0.25	0.06	0.29	0.28
ZnO	0.1	-	0.02	0.02
CO_2	-	0.3	2.38	3.22
As	-	-	0.039	0.039
H_2O	-	-	0.92	1.01
Water of cryst.	1	3	-	-

Source: Industrial Minerals, July, 1985.
Economics of Manganese, 1986.

TABLE XVII

NON-METALLURGICAL MANGANESE ORE - HYDROMETALLURGICAL GRADE

Mn	53
SiO_2	1.4
Al_2O_3	5.34
Fe	2.04
Size	3 x 12 mm

Source: Industrial Minerals, July, 1985.

TABLE XVIII

NON-METALLURGICAL MANGANESE ORE - WELDING FLUX GRADES

	Jan de Poorter		Imini	Comilog	BHP
	Mangalox H	Mangalox K	Tiharatine		Prem. fines
MnO_2	80	-	41.1	77.45	-
Mn	-	-	-	-	52
MnO	2	-	48.98	3.33	-
Mn_3O_4	-	69	-	-	-
SiO_2	8	7	1.25	2.01	3.5
Al_2O_3	2	0.5	0.72	-	3.5
Fe_2O_3	1	-	0.43	4.02	-
FeO	-	15	-	-	-
Fe	-	-	-	-	3
TiO_2	-	-	0.02	-	-
CaO	0.9	4	2.43	-	-
MgO	0.4	0.5	0.94	-	-
BaO	2	0.5	0.3	0.28	0.4
Na_2O	0.2	0.2	0.05	-	-
K_2O	0.3	0.2	0.03	-	0.8
PbO	0.6	-	0.1	-	-
Pb	-	-	-	0.005	-
SO_3	-	-	0.12	-	-
S	0.03	0.05	-	0.018	-
P_2O_5	-	-	0.044	-	-
P	0.04	0.04	-	0.114	0.08
V	-	-	-	0.022	-
NiO	-	-	0.006	-	-
CoO	-	-	0.019	-	-
CuO	-	-	0.025	-	-
ZnO	-	-	0.07	-	-
CO_2	-	0.8	2.04	-	-
As	-	-	0.013	0.007	-
H_2O	-	-	1.3	-	-
Water of cryst.	1.5	-	-	-	-
L.o.i.	-	2	-	-	-

Source: Industrial Minerals, July, 1985.
Economics of Manganese, 1986.

TABLE XIX

NON-METALLURGICAL MANGANESE ORE - GLASS GRADES

	Typical Analyses	
	Black*	Grey*
MnO_2	93.12	82.5
MnO	0.56	0.15
SiO_2	2.35	5.66
Al_2O_3	0.85	1.23
CaO	0.25	0.25
MgO	0.26	1.6
CO_2	0.4	3.45
Fe_2O_3	0.49 - 0.61	0.49 - 0.61
Size	(5% residue at 53 microns)	

* finished colour

Source: Industrial Minerals, July, 1985.

TABLE XX

NON-METALLURGICAL MANGANESE ORE - FERRITE GRADES

	Jan de Poorter		Imini
	Mangalox H	Mangalox J	UF92
MnO_2	80	89	92.74
MnO	2	1.5	0.65
SiO_2	8	0.5	2.05
Al_2O_3	2	0.8	0.8
Fe_2O_3	1	1.5	0.21
TiO_2	-	0.05	0.04
CaO	0.9	0.9	0.71
MgO	0.4	0.02	0.42
BaO	2	2.9	0.36
Na_2O	0.2	-	0.02
K_2O	0.3	0.2	0.17
PbO	0.6	0.07	0.13
SO_3	-	0.8	0.04
S	0.03	-	-
P_2O_5	-	0.2	0.055
P	0.04	-	-
NiO	-	0.02	0.013
CoO	-	0.01	0.014
CuO	-	0.25	0.29
ZnO	-	0.1	0.02
CO_2	-	-	0.71
As	-	-	0.04
H_2O	-	-	0.5
Water of cryst.	1.5	1	-

Source: Industrial Minerals, July, 1985.
Economics of Manganese, 1986.

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TABLE XX

NON-METALLURGICAL MANGANESE ORE - FERRITE GRADES

	Jan de Poorter		Imini
	Mangalox H	Mangalox J	UF92
MnO_2	80	89	92.74
MnO	2	1.5	0.65
SiO_2	8	0.5	2.05
Al_2O_3	2	0.8	0.8
Fe_2O_3	1	1.5	0.21
TiO_2	-	0.05	0.04
CaO	0.9	0.9	0.71
MgO	0.4	0.02	0.42
BaO	2	2.9	0.36
Na_2O	0.2	-	0.02
K_2O	0.3	0.2	0.17
PbO	0.6	0.07	0.13
SO_3	-	0.8	0.04
S	0.03	-	-
P_2O_5	-	0.2	0.055
P	0.04	-	-
NiO	-	0.02	0.013
CoO	-	0.01	0.014
CuO	-	0.25	0.29
ZnO	-	0.1	0.02
CO_2	-	-	0.71
As	-	-	0.04
H_2O	-	-	0.5
Water of cryst.	1.5	1	-

Source: Industrial Minerals, July, 1985.
Economics of Manganese, 1986.

level of manganese (whether as Mn, MnO_2 or MnO) but maximum levels of all other elements.

The tables illustrate a degree of interchangeability of ores between end uses. For example, Mangalox K supplied by Jan de Poorter, processor of manganese ores, can be used for both brick pigment and welding flux and Mangalox H can be used for both welding flux and ferrite manufacture.

CURRENT DEMAND FOR MANGANESE ORE

INTERNATIONAL TRADE

Total world trade in manganese ores amounted to approximately 6.35 million tonnes in 1984, or about 27 per cent of total production. The bulk of ores are consumed domestically in the production of manganese ferroalloys and do not enter international trade.

In 1984, the largest exporter was South Africa which accounted for slightly under 40 per cent of total exports, as shown in Table XXI. Other major exporters were Gabon (20 per cent), the USSR (17 per cent) and Australia (11 per cent). These four countries combined to account for almost 85 per cent of the world total export trade in manganese ores.

Although the focus of this assignment is on non-metallurgical manganese ores, available trade statistics do not distinguish between the end-uses. The major producers of non-metallurgical ores are Australia, Brazil, Gabon, Ghana, Greece, Indonesia, Mexico, Morocco and South Africa. This section of the report, therefore, concentrates on the exports trend of these countries only, over the ten-year period from 1975 to 1984.

Australia registered a 30 per cent increase in its manganese ore exports from Groote Eylandt between 1975 and 1984. Exports of ores fell dramatically during the world recession in 1981 and 1982, since 90 per cent of ores were of metallurgical grade. The possibility of a joint venture

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TABLE XXI

EXPORTS OF MANGANESE ORES AND CONCENTRATES RECORDED BY MAJOR EXPORTING COUNTRIES

1984

(000t gross weight)(1)

Country of Destination	Exporting Country: Australia	Brazil	China	France	Gabon	Ghana	Mexico	Morocco	Netherlands	South Africa	USA	USSR	Others	Total
BLEU	-	-	-	3.3	-	-	-	-	2.9	-	-	-	1.4	7.6
Bulgaria	-	-	-	-	-	-	-	-	-	-	-	74.0	-	74.0
Canada	-	-	-	-	-	-	-	-	-	-	49.8	-	-	49.8
Colombia	-	-	-	-	-	-	-	-	-	-	6.0	-	-	6.0
Czechoslovakia	-	-	-	-	-	-	-	1.0	-	-	-	300.0	-	301.0
France	(44.1)	(41.1)	-	-	(629.0)	-	(19.7)	28.0	3.7	(247.5)	99.5	-	-	1,112.6
Gabon	-	-	-	17.1	-	-	-	-	-	-	-	-	-	17.1
East Germany	-	-	-	-	-	-	-	-	1.1	-	-	68.0	-	69.1
West Germany	(100.0)	(10.0)	-	-	(38.0)	-	(1.4)	20.0	11.4	(320.0)	-	-	0.4	501.2
Italy	-	(22.0)	-	19.0	(151.0)	-	-	5.0	3.2	(62.0)	34.6	-	3.6	300.4
Japan	(515.7)	(36.0)	(11.2)	-	(82.0)	(47.6)	(6.6)	-	-	(1,201.0)	1.3	-	-	1,901.4
North Korea	-	-	-	-	-	-	-	-	-	-	-	21.0	-	21.0
Mexico	-	-	-	-	-	-	-	-	-	-	23.6	-	-	23.6
Norway	(22.0)	(47.0)	-	31.1	(238.0)	(43.0)	(41.0)	-	-	(292.0)	-	-	-	714.1
Poland	-	-	-	-	-	-	-	-	-	-	-	549.0	-	549.0
South Africa	-	-	-	-	-	-	-	-	8.0	-	-	-	-	8.0
Spain	-	-	-	-	-	-	-	7.0	1.0	-	-	-	-	8.0
Switzerland	-	-	-	1.4	-	-	-	-	0.5	-	-	-	3.6	5.5
Taiwan	-	-	-	-	-	-	-	-	-	-	-	-	4.4	4.4
UK	(5.0)	(129.2)	-	-	-	(10.9)	-	7.0	0.6	(116.7)	-	-	-	269.4
USA	(36.0)	(80.1)	-	2.5	(120.6)	-	(37.0)	-	-	(32.8)	-	-	1.9	310.9
Yugoslavia	-	-	-	0.3	-	-	-	-	-	-	-	35.0	-	35.3
Others nsl	-	-	-	1.7	(0.3)	-	-	2.0	14.2	(0.2)	0.8	34.0	5.8	59.0
Total	(722.8)	(365.4)	(11.2)	76.4	(1,258.9)	(101.5)	(105.7)	70.0	46.6	(2,272.2)	215.6	1,081.0	21.1	6,348.4

(1) Figures in brackets are estimated from recorded imports.

Source: Economics of Manganese, 1986.

between Groote Eylandt and China, following the sale of 80,000 tonnes to China in 1984, would further boost Australian ore exports. Australia has diversified its products by focussing on battery-grade ore production in addition to establishing new customers.

Both Brazil and Mexico have halved their respective ore exports since 1975 and their ores are increasingly being consumed in their domestic ferromanganese industries. Brazil's main customers are the United Kingdom, Norway, Japan and France. Mexico sells mainly to the United States, Colombia and Japan. Mexico is the main supplier of battery grade ores to Colombia, Brazil and the United States.

Exports of manganese ore from Gabon totalled 1.26 million tonnes in 1984, only marginally higher than the 1983 level (which was the lowest since 1978) and 41 per cent off the peak in 1980. SFPO of France which has a substantial holding in Comilog purchased half the 1984 exports. Norway's Elkem owns 6 per cent of Comilog and purchased 20 per cent of Gabonese exports in 1984. Comilog of Gabon is the world's largest producer of natural battery-grade manganese ore and, currently, non-metallurgical grades of ore account for nearly 10 per cent of total exports.

The level of exports from Ghana and Morocco has fallen off over the last 10 years, mainly because of diminishing ore reserves. Ghana is no longer the world's leading supplier of battery-grade ore. Although a new nodulizing plant for

producing battery-grade MnO_2 was completed in 1983, power shortages and transport problems have forced it out of commission since. Morocco exports 100 per cent of its high-quality, ultrafine grade and high-value manganese ores used solely in non-metallurgical application. The leading markets are France (40 per cent) and West Germany (29 per cent).

Exports of manganese ores from Greece are relatively insignificant compared to the other countries. Its ores are predominantly battery grade, however, and the decline in export volume since 1975 reflects the domestic treatment of ores to produce manganese dioxide. The main markets for Greek ores are Yugoslavia and Spain. There is also one Japanese owned EMD plant in Greece which exports primarily to Belgium and Luxemburg.

World import trade in manganese ores declined from 11.2 million tonnes in 1975 to 6.4 million tonnes in 1984, or a near 43 per cent drop; Table XXII shows import trade in 1984. The primary reason is the trend towards trade in the form of ferromanganese and silicomanganese by the world steel producing countries, rather than as manganese ore. The decline in world demand for ores was exacerbated by the recession in the iron and steel industry during the early 1980's.

The major importers of manganese ores in the non-socialist world are Japan, France, Norway, West Germany and the United States. These countries combined to account for three-

TABLE XXII

IMPORTS OF MANGANESE ORES AND CONCENTRATES RECORDED BY MAJOR IMPORTING COUNTRIES

1984

(000t gross weight)[1]

Country of Origin	Importing Country: Bulgaria	Czecho-slovakia	France	East Germany	West Germany	Italy	Japan	Nether-lands	Norway	Poland	UK	USA	Others	Total
Australia	-	-	44.1	-	100.0	-	515.7	-	21.8	-	5.0	36.0	-	722.6
BLEU	-	-	-	-	-	-	-	5.0	-	-	0.6	-	-	5.6
Brazil	-	-	41.1	-	10.0	22.0	36.0	-	46.9	-	129.2	80.1	-	365.3
Canada	-	-	-	-	19.0	-	-	-	-	-	-	-	-	19.0
China	-	-	-	-	-	-	11.2	-	-	-	-	-	-	11.2
Congo	-	-	-	-	20.0	-	7.0	-	-	-	-	-	-	27.0
France	-	-	-	-	-	14.0	-	1.0	54.8	-	0.6	-	0.3	70.7
Gabon	-	-	629.0	-	38.0	151.0	82.0	-	237.5	-	-	120.6	0.3	1,258.4
Ghana	-	-	-	-	-	-	47.6	-	43.5	-	10.9	-	-	102.0
Indonesia	-	-	-	-	-	-	6.0	-	-	-	-	-	-	6.0
Mexico	-	-	19.7	-	1.4	-	6.6	-	40.7	-	-	37.0	-	105.4
Morocco	-	(1.0)	22.6	-	15.6	5.0	-	-	-	-	6.0	0.1	-	50.3
Netherlands	-	-	0.7	(1.1)	8.3	3.0	-	-	-	-	0.8	-	0.4	14.3
South Africa	-	-	247.5	-	320.0	62.0	1,201.0	-	291.8	-	116.7	32.8	0.2	2,272.0
USSR	(74.0)	(300.0)	-	(68.0)	-	-	-	-	-	(549.0)	-	-	-	991.0
Others nsl	-	-	3.0	-	3.6	15.7	275.0	44.0	0.1	-	0.1	0.1	0.1	341.7
Total	(74.0)	(301.0)	1,007.7	(69.1)	535.9	272.7	2,188.1	50.0	737.1	(549.0)	269.9	306.7	1.3	6,362.5

(1) Figures in brackets are estimated from recorded exports.

Source: Economics of Manganese, 1986.

quarters of total world import trade (including socialist countries) in 1984. Japan, West Germany and the United States require ores for the iron and steel sector, while France and Norway are two of the world's largest exporters of ferro and silicomanganese. Canada does not have domestic manganese ore production and is completely reliant on imports to fulfill its annual manganese ore requirements.

The trend in ore imports by the major importers is shown in Table XXIII. Discrepancies between figures in Tables XXI, XXII and XXIII are due to differences in reporting sources and are not typographical errors.

In summary, principal sources of manganese ores and concentrates supply for the major importing nations are:

Importer	Exporters
Japan	South Africa, Australia, Gabon
France	Gabon, South Africa
West Germany	South Africa, Australia
U.S.A.	Gabon, Brazil
Canada	Gabon, South Africa, Brazil

Trade in Manganese Dioxide

Partial statistics exist covering trade in manganese dioxide and are published by The Manganese Centre.

The coverage is incomplete since the term manganese dioxide may cover either, or both, natural ores and synthetic manganese dioxide (EMD or CMD), and reporting countries do not follow any particular convention.

TABLE XXIII

IMPORTS OF MANGANESE ORES AND CONCENTRATES OF SELECTED COUNTRIES

('000 tonnes)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Japan	3,832.4	3,356.1	2,753.5	2,011.7	2,692.0	2,953.3	2,492.7	2,146.4	1,623.2	2,188.1	N.A.
France	1,157.6	1,014.6	922.7	958.4	1,274.8	1,225.9	880.8	921.8	745.6	1,007.7	N.A.
Norway	1,072.9	982.4	591.4	803.1	815.1	807.7	484.6	764.1	623.3	737.1	N.A.
West Germany	733.5	610.5	453.2	673.0	716.8	489.5	606.9	393.5	434.3	535.8	N.A.
United States	1,428.0	1,195.0	844.5	497.0	453.4	633.2	587.2	208.	344.2	306.7	351.7
Canada	69.8	119.0	57.6	136.4	45.2	95.2	119.7	71.7	42.3	77.5	102.0

Source: Manganese Centre; British Geological Survey; EMR.

For the purposes of this assignment, imports of manganese dioxide by the United States and Canada have been assessed on the basis of export data reported by The Manganese Centre, as shown in Table XXIV.

Table XXIV indicates that the principal suppliers of manganese dioxide to the United States are Japan and Mexico. Exports from Japan into the United States have increased substantially, from 6,490 tonnes in 1980 to 19,000 tonnes in 1984. The majority of this is EMD and provides an indication as to the increased usage of EMD in battery manufacture in the United States over the past five years.

Japan and the United States are the principal suppliers of manganese dioxide to Canada. Again, this would mostly be EMD for battery manufacture since the United States statistics specifically exclude manganese dioxide for pigments.

APPARENT CONSUMPTION OF MANGANESE ORES

Manganese ores are used in the metallurgical, chemical and battery industries. In the developing, steel-producing countries, the iron and steel sector would account for almost the entire manganese consumption. Demand for non-metallurgical uses is highest in industrialized countries, where the world's manganese chemicals and dry-cell batteries production is concentrated.

In this section of the report, world manganese consumption is discussed on the basis of apparent consumption statistics, followed by review of the United States, Canada and Japan for

TABLE XXIV

UNITED STATES AND CANADA: APPARENT IMPORTS OF MANGANESE DIOXIDE
(tonnes)

UNITED STATES

Export Source:	1980	1981	1982	1983	1984
Denmark	-	-	-	-	27.0
Greece	-	1,431.0	2,070.0	-	N/A
Ireland	-	344.0	181.0	308.0	N/A
Japan	6,490.0	-	14,540.0	16,520.0	19,020.0
Mexico	N/A	14,100.0	8,800.0	5,400.0	8,600.0
United Kingdom	20.0	-	-	55.0	70.0
Total[1]	6,510.0	15,875.0	25,591.0	22,283.0	27,717.0

CANADA

Export Source:	1980	1981	1982	1983	1984
Greece	N/A	504.0	357.0	-	N/A
Japan	200.0	12,060.0	170.0	900.0	1,210.0
United Kingdom	-	20.0	20.0	37.0	57.0
United States	1,120.0	1,404.0	1,257.0	1,130.0	452.0
Total[1]	1,320.0	13,988.0	1,804.0	2,067.0	1,719.0

[1] Total of figures recorded

Source: Manganese Centre, Manganese Trade Statistics

which somewhat more detailed demand figures are available.

There are no comprehensive manganese consumption statistics available on a country-by-country basis. Table XXV shows calculations by the USBM for 1983 on world apparent consumption of manganese ores and concentrates (production + imports - exports). Apparent consumption of ores and concentrates in any one country, however, does not necessarily equal total manganese consumption. For example, the United States, West Germany and the United Kingdom, import manganese in the form of ferroalloys which contribute to total manganese consumption.

Total world apparent consumption of manganese ores and concentrates totalled 23.2 million tonnes in 1983. The USSR is the world's largest consumer with 9.4 million tonnes or 40 per cent of the world total. Since the iron and steel sector traditionally accounts for over 90 per cent of ore consumption, the remaining major consumers are also leading steel-producing countries: India with 8 per cent of the world total, Japan and China each with 7 per cent, Brazil 6 per cent and South Africa 5 per cent, primarily for production of ferroalloys rather than steel.

In North America, the United States and Canada together, accounted for only 1.5 per cent of world apparent manganese ore consumption in 1983. United States consumption of manganese is in the form of ferroalloys instead of ores, while Canadian steel production capacity is relatively small

TABLE XXV

APPARENT CONSUMPTION OF MANGANESE ORES AND CONCENTRATES

1983

(tonnes)

Country	Production	Imports	Exports	Apparent Consumption
Argentina	6,926	-	-	6,926
Australia	1,354,000	-	910,829	443,171
Austria	-	362	-	362
BLEU	-	162,653	-	162,653
Brazil	2,091,631	19,206	747,436	1,363,401
Bulgaria	45,000	-	-	45,000
Canada	-	42,260	-	42,260
Chile	26,052	-	-	26,052
China	1,597,000	-	22,713	1,574,287
Colombia	-	1,477	-	1,477
Czechoslovakia	-	459,000	-	459,000
Denmark	-	322	-	322
France	-	745,625	-	745,625
Gabon	1,867,000	-	1,287,317	579,683
West Germany	-	434,261	4,020	430,241
Ghana	173,000	-	162,845	10,155
Greece	4,636	-	1,429	3,207
Hungary	59,000	-	9,608	49,392
India	1,320,000	459,000	-	1,779,000
Italy	7,205	385,550	1,009	391,746
Japan	77,000	1,497,787	1,973	1,572,814
South Korea	-	196,457	-	196,457
Mexico	350,011	297	102,417	247,891
Morocco	73,515	316	57,860	15,971
Netherlands	-	44,389	43,208	1,181
New Zealand	-	643	-	643
Norway	-	623,305	1,522	621,783
Philippines	2,242	3,981	1,381	4,842
Poland	-	574,194	-	574,194
Portugal	-	68,587	-	68,587
Romania	28,000	220,000	-	248,000
Saudi Arabia	-	7,424	-	7,424
South Africa	2,886,000	4,037	1,810,771	1,079,266
Sweden	-	24,557	509	24,048
Taiwan	-	196,195	-	196,195
Thailand	6,000	-	-	6,000
Turkey	3,204	1,910	-	5,114
UK	-	368,494	1,414	367,080
USA	-	334,119	17,522	316,597
USSR	10,400,000	4,000	1,037,837	9,366,163
Venezuela	-	5,150	-	5,150
Yugoslavia	26,000	130,169	5,175	150,994
Total	22,403,422	7,015,727	6,228,795	23,190,354

Source: US Bureau of Mines
Economics of Manganese, 1986.

compared to other countries.

The countries for which there are some available manganese consumption data by end use sector are the United States, Canada and Japan. In order to put these data into the context of the analysis of apparent consumption, these countries have been selected, with West Germany, Brazil and India, for presentation of a longer history of apparent consumption. West Germany was selected as a major European economy which might be expected to consume a relatively large quantity of non-metallurgical manganese ore. Brazil and India were selected as important producers of manganese ore, with large domestic steel industries.

The apparent consumption history for the United States, Canada, Japan and West Germany over the period 1975 to 1984, shown in Table XXVI, indicate that there have been major reductions in consumption and confirms two trends identified earlier in this report:

- generally, manganese ferroalloys have accounted for a greater proportion of total manganese demand and this has offset, to an extent, the steady decline in consumption of ores;

- improvements in steel making techniques have reduced the overall requirement for manganese per unit of output.

The consumption trend, however, is significantly different in the two developing country examples of Brazil and India. Brazilian apparent consumption of ores has nearly tripled since 1975, while India has more than doubled its

TABLE XXVI

APPARENT CONSUMPTION OF MANGANESE ORES OF SELECTED COUNTRIES

('000 tonnes)

Industrialized World	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
U.S.A.	1,224.4	1,021.0	686.8	277.8	393.5	410.7	807.0	173.9	316.6	83.5
Japan	3,986.4	3,492.0	2,874.3	2,110.8	2,773.8	3,031.5	2,578.7	2,222.9	1,696.3	2,271.8
West Germany	730.0	605.6	446.3	670.9	714.8	488.1	604.7	392.0	430.2	535.1
Canada	69.8	119.0	57.6	136.4	45.2	95.2	119.7	71.7	42.3	77.5
Developing World										
Brazil	616.0	641.6	1,021.9	890.8	1,173.1	1,273.1	1,038.9	1,506.3	1,363.8	1,815.0
India	769.1	1,045.8	1,315.7	993.8	1,130.2	1,466.3	1,097.0	N.A.	1,779.0	N.A.

N.A. Not Available

Sources: British Geological Survey; USBM; EMR

consumption. Following the development of the Carajas deposit in the early 1980's, Brazil is now the third largest producer of manganese ores and its ferroalloys production capacity has increased concomitantly. Although about 60 per cent of ferroalloys are exported, the remaining 40 per cent is consumed domestically to sustain the domestic steel industry. India's manganese ores have been channeled towards its own ferromanganese industry by government policy since 1973.

Manganese Consumption in the United States

The United States market for manganese ores currently is approximately 600,000 tonnes per year, with the non-metallurgical uses accounting for some 100,000 tonnes per year. For the past three years, imports of manganese ores into the United States have ranged between 305,000 and 350,000 tonnes per year. The difference between imports and consumption of manganese ores is accounted for by sales from the United States National Defense Stockpile.

The General Services Administration (GSA), which administers the stockpile, suspended sales of excess material from October, 1985, to comply with a statutory restriction prohibiting sales when the balance in the Stockpile Transaction Fund exceeds US$250 million. Natural battery and metallurgical manganese ores were among the excess materials for which offers for disposal were withdrawn. Industry sources indicate that some two years' supply only of non-

metallurgical material is available from the United States stockpile.

The United States non-metallurgical manganese industry comprises relatively few companies, almost all of which have interests which extend across several end use sectors.

American Minerals is the leading grinder of manganese ores and has capacity to process 45,000 tonnes per year at four plants in Texas, Illinois, New Jersey and Delaware. Its major markets are in the ceramic, chemicals, battery and zinc industries. Prince Manufacturing is the second largest grinder of ores.

Companies which supply the battery industry with ores and EMD are Foote Mineral Co., Kerr-McGee Chemical Corp., Eveready and ESB Materials.

The companies which supply agricultural manganese include Chemetals, Eagle Pitcher Industries, Stoller Chemical and Frit Industries.

Chemetals Inc. is a subsidiary of Sté. Européenne des Dérives du Manganese (Sedema) of Belgium, which itself is one of the world's largest suppliers of processed manganese ores and chemicals. Chemetals supplies a wide range of manganese products to the North American market and is the only domestic producer of CMD.

Carus Corporation is the only North American producer of potassium permanganate.

Detailed figures for the consumption of manganese ores and

concentrates, divided by end use, are available only for the United States. Table XXVII shows United States consumption by industry between 1975 and 1984, and the estimate of total consumption for 1985. Between 1975 and 1984, total consumption dropped from just over one million tonnes to 570,000 tonnes. This decline was due both to higher imports of manganese ferroalloys and to lower unit consumption of manganese in steel production which fell 28.6 per cent between 1975 and 1984.

In the early 1980's, consumption was further depressed by the low levels of steel production: between 1981 and 1983 alone, United States consumption of manganese ore fell 35 per cent from 932,000 tonnes to 607,000 tonnes. Metallurgical markets accounted for about 70 per cent of United States consumption of manganese ores, on average, between 1975 and 1984.

In the non-metallurgical end use sectors, the principal ore consuming industries are chemicals and batteries which, together, consumed about 60,000 tonnes in both 1975 and 1984. The peak years for ores consumption in these two sectors were in 1977 and 1978 with a combined total of 71,000 tonnes in each year. Although the total volume represented by the chemical and battery industries showed practically no change between 1975 and 1984, chemical sector consumption of manganese fell by 34 per cent over the same period. This decline largely reflects the decision by United States

TABLE XXVII

UNITED STATES - DEMAND PATTERN FOR MANGANESE ORES 1975 - 1985

(Thousand tonnes)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985[P]
METALLURGICAL											
Construction	226	216	218	253	264	222	227	138	137	155	24%
Transportation	236	270	272	288	269	195	195	105	117	126	18%
Machinery	168	169	170	196	197	150	154	84	82	88	11%
Cans and Containers	53	57	54	54	55	45	41	28	26	35	5%
Appliances and Equipment	43	46	48	52	53	45	45	27	30	33	5%
Oil and Gas Industries	58	48	57	67	63	73	82	36	25	33	5%
Sub-total	784	806	819	910	901	730	714	418	417	470	68%
NON-METALLURGICAL											
Chemicals	47	43	55	55	54	45	45	26	20	31	5%
Batteries	16	16	16	16	15	15	15	19	23	51	6%
Others	183	372	490	254	163	144	128	147	147	99	25%
Sub-total	243	431	561	325	232	204	218	192	190	181	32%
Total	1,027	1,237	1,380	1,235	1,133	934	932	610	607	571	100%

P - Preliminary figures shown as percentage of total demand, Withheld pending official release.

Source: USBM

chemical producers to terminate production of the fungicide Maneb in the early 1980's because its residues were found to be carcinogenic. The decline in chemical industry consumption of manganese was offset by the 121 per cent advance in battery industry demand between 1975 and 1984. The gains made by battery-operated calculators, cameras and music equipment greatly increased the demand for dry-cell batteries during the period.

Manganese Consumption in Canada

The Canadian market for manganese ores is approximately 100,000 tonnes per year. Non-metallurgical uses of manganese ores in Canada range between 5,000-10,000 tonnes annually and 1986 consumption was approximately 7,000 tonnes.

Generally speaking, Canadian non-metallurgical requirements for manganese are supplied by producers, grinders, refiners and manufacturers of manganese compounds located in the United States. These companies include American Minerals Inc., Prince Manufacturing, Frit Industries, Carus Corporation, Eagle Pitcher Industries, Foote Minerals, Kerr-McGee Chemical Corporation, ESB Materials, Eveready Battery Company Inc. and Chemetals. Very minor portions of the total Canadian market are met by producers in Spain, China, Japan, Mexico and other sources.

Although a detailed manganese consumption breakdown by each end use sector, similar to that prepared by the USBM, is not available for Canada, Energy Mines & Resources, Canada,

does report total manganese consumption broken down into metallurgical and battery and chemical grades. The quantity of manganese ores consumed in Canada fell by almost one-third between 1975 and 1984. This decline reflected the 33.4 per cent drop in metallurgical grade ore consumption since 1975. The declining trend was particularly apparent in the early 1980's when the peak of almost 285,000 tonnes in 1981 fell 94,000 tonnes in 1983. This was due to the low level of steel sector demand for manganese ferroalloys during the 1982-1983 recession.

Table XXVIII shows that only 3 per cent of manganese ores consumed in Canada is in the non-metallurgical sector. Total Canadian non-metallurgical manganese ore demand rose throughout the decade and recorded a 37.5 per cent increase between 1975 and 1984. In conjunction with the falling consumption in metallurgical applications, rising consumption by the battery and chemical industries also led to a doubling in their relative market share from 1.5 per cent of total ores consumption in 1975 to 3 per cent by 1984.

Statistics Canada reports in its series "Census of Manufactures" the annual consumption of manganese dioxide by Canadian battery and clay products manufacturers. (Statistics Canada, Battery Manufacturers, cat. no. 43-208 and 43-213; Clay Products Industries, cat. no. 44-215 and 44-218). There are no data on manganese use in the survey of chemical manufacturers.

TABLE XXVIII

CANADA, MANGANESE ORE CONSUMPTION

1975 - 1984
(gross weight tonnes)

Year	Metallurgical Grade	Battery and Chemical Grade	Total	Battery and Chemical Grade As % of Total
1975	158,600	2,400	161,000	1.5
1976	236,400	2,200	238,600	0.9
1977	198,100	2,400	200,500	1.2
1978	198,600	2,800	201,400	1.4
1979	58,600	3,100	61,700	5.0
1980	154,300	3,300	157,600	2.1
1981	284,600	4,300	288,900	1.5
1982	127,500	3,400	130,900	2.6
1983	93,900	3,200	97,100	3.3
1984	105,600	3,300	108,900	3.0

Source: Canadian Minerals Yearbook, Dept. of Energy Mines & Resources.

The Statistics Canada data on battery manufacture show consumption of manganese dioxide (presumed to be both natural MnO_2 and EMD from the interview procedure) varying between 2,000 tonnes and 3,200 tonnes per year over the period 1975-1983. (Table XXIX). This is in contrast to the steady upward trend for consumption of ores in batteries in the United States, and also the upward trend in manganese dioxide exports by Japan to the United States.

Consumption of manganese dioxide in the clay products industry (Table XXX) has declined from generally above 2,000 tonnes per year in the late 1970's to well below 1,500 tonnes per year since 1982.

Manganese Consumption in Japan

The Japan Mining Association provided the consultants with a time-series on Japanese manganese ore consumption between 1975 and 1983, broken down by steel sector and other industries (chemical and battery manufacturers being the principals). Table XXXI shows that non-metallurgical demand for manganese ores accounted for less than 2 per cent of total Japanese manganese demand until the early 1980's. As a result of a 36.4 per cent increase in non-metallurgical sector consumption between 1980 and 1983, combined with the 36.7 per cent drop in steel sector demand, the market share represented by the non-metallurgical sector increased to 3.5 per cent in 1983.

Japanese production of manganese ferroalloys fell 44 per

TABLE XXIX

CANADIAN BATTERY MANUFACTURERS

CONSUMPTION OF MANGANESE DIOXIDE

Year	Tonnes
1975	2,657
1976	2,231
1977	2,782
1978	2,147
1979	2,470
1980	3,124
1981	2,043
1982	2,085
1983	3,184

Source: Statistics Canada

TABLE XXX

CANADIAN CLAY PRODUCTS INDUSTRY

CONSUMPTION OF MANGANESE DIOXIDE

Year	Tonnes
1975	1,802
1976	2,278
1977	2,260
1978	1,859
1979	2,245
1980	2,067
1981	2,044
1982	1,049
1983	1,243
1984	1,320

Source: Statistics Canada

TABLE XXXI

JAPANESE CONSUMPTION OF MANGANESE ORE
('000 tonnes)

Years	Steel Sector	Others	Total	Others as a % Of Total
1975	3,205	34	3,239	1.1
1976	3,111	33	3,244	1.1
1977	2,662	36	2,698	1.4
1978	2,329	39	2,368	1.6
1979	2,656	41	2,697	1.5
1980	2,651	44	2,695	1.6
1981	2,350	54	2,404	2.2
1982	2,145	57	2,202	2.6
1983	1,678	60	1,738	3.5

Source: Japan Mining Industry Association

cent between 1975 and 1983, as producers suffered from the recession in the steel industry and from competition from imported ferromanganese (particularly from South Africa and Brazil). This resulted in a large reduction in Japanese requirements for manganese ores as a raw material for its ferroalloy production. Consumption of ores by the non-metallurgical sector, on the other hand, experienced a 76.4 per cent increase in demand between 1975 and 1983. Japan is the world's largest EMD producer, with 35 per cent of the world's total EMD production capacity. Rapid growth in both export and domestic demand for EMD in dry alkaline batteries has meant that the consumption of natural carbonate manganese ores has also risen rapidly.

DEMAND FOR MANGANESE IN NON-METALLURGICAL END-USE SECTORS

Manganese is used in a range of non-metallurgical applications in the form of natural ores and manganese chemicals, of which the principal ones are manganese dioxide, manganous oxide, manganese sulphate and potassium permanganate.

The specifications applied to natural manganese ores for various end uses were discussed in the supply section of this report. In this introduction to manganese demand, the ores and the manganese products derived from them are described briefly.

In general, the technical demands imposed on natural manganese ores have led to the use of only the higher grade ores in untreated form, except for grinding. At the same

time, the production of most manganese chemicals, other than electrolytic manganese dioxide, includes a dissolution stage. The carbonate ores are readily acid soluble, but dioxide ores have to be reduced to manganous oxide in order to achieve acid solubility.

Manganese Ores

As noted earlier, there are three types of commercially traded manganese ores:

- oxide ores
- carbonate ores
- silicate ores

The first two types are by far the more important, generally, and, for non-metallurgical end applications, are the only ones used.

Manganese Dioxide

Manganese dioxide occurs naturally in the form of the mineral, pyrolusite. It is also produced by several chemical methods from naturally occurring ores, both oxide and carbonate types, and from ferromanganese. Natural, high grade manganese dioxide ores may also be treated by chemical means to enhance the chemical activity of the manganese dioxide.

Natural manganese dioxides contain tetravalent manganese. In the mineral pyrolusite, approximately half of the oxygen is theoretically available. In order to maximize the oxidizing potential, natural ores are 'activated' (or, alternatively, a synthetic manganese dioxide is produced).

Natural or activated natural ores are used in batteries, as pigments, in ferrites and in welding. Activated natural manganese dioxide are used primarily in batteries.

Electrolytic manganese dioxide (EMD) is characterized by its ability to function extremely well as a solid-state oxygen electrode in dry cell batteries over a wide range of discharge conditions. EMD is also used in production of ferrites where performance and control of impurities are important.

Partly because of the occurrence of such ores domestically, carbonate ores have been favoured for EMD production in Japan and are imported from Gabon, China and Brazil. Oxide ores are used by most other producers of EMD.

Table XXXII shows the major producers of EMD and their capacity.

A typical analysis of battery grade EMD is given in Table XXXIII, with the analysis of ferrite grade EMD, produced by Toyo Soda of Japan, for comparison.

Chemical manganese dioxide (CMD) is produced either by chemical reduction of permanganate or by thermally decomposing manganese salts, such as manganese carbonate or manganese nitrate.

CMD is produced only in Japan and Belgium. It is used in carbon-zinc and magnesium-chloride cells but is not suitable for alkaline batteries. The Belgian producer, Sedema, has developed a CMD product for use in alkaline batteries but

TABLE XXXII

WORLD PRODUCTION CAPACITY FOR EMD, 1986
(tonnes per year)

Company	Capacity
JAPAN	
Mitsui Metal Mining	25,200
Toyo Soda Industry	24,000
Daiichi Carbon	3,000
Japan Chemical Industry	12,000
IRELAND	
Mitsui Metal Mining	12,000
GREECE	
Toyo Soda Industry	12,000
WEST GERMANY	
Hoechst AG	11,000
SPAIN	
Cegasa	5,000
U.S.A.	
Union Carbide	11,000
Kerr-McGee	11,000
Foote Minerals	10,200
ESB	8,000
S. AFRICA	
Delta	20,000
USSR	24,000
China	17,000
Total	185,400

Source: Economics of Manganese, 1986, Roskill's Letter from Japan, No. 116 January, 1986)

TABLE XXXIII

ANALYSES OF BATTERY GRADE AND FERRITE GRADE EMD

BATTERY GRADE, %

MnO_2	92 ± 0.30	SB	0.0001
Mn	60 ± 0.12	As	0.0003
H_2O	1.52 ± 0.20	Mo	0.0002
Fe	0.008	Na	0.24
Pb	0.0007	NH_3	0.001
Cu	0.0003	SiO_2	0.02
Ni	0.0005		
Co	0.0008		
Cr	0.0008		

FERRITE GRADE, %

MnO_2	94.00 min.
Moisture	2.50 max.
SiO_2	0.03 max.
CaO	0.05 max.
MgO	0.03 max.
SO_4	1.10 max.
Na	0.05 max.
$(Fe+Al)_2O_3$	0.10 max.
99.5% minus	100 mesh
95.0% minus	325 mesh

Source: Economics of manganese, 1986

this has not yet gained acceptance.

Table XXXIV shows a typicial analysis of Sedema 'Faradiser M' battery grade CMD.

Manganese Chemicals

Table XXXV gives the names, formulae and principal end uses for manganese chemicals. In volume terms, manganese dioxide, manganese oxide, manganese sulphate and potassium permanganate are by far the most important.

The key non-metallurgical end uses for manganese are the following:

- Batteries
- Bricks and Tiles
- Agriculture
- Water Purification
- Hydrometallurgy
- Welding Fluxes
- Glass
- Ferrites
- Others

This section of the report describes briefly all the non-metallurgical end use sectors.

Batteries

Manganese dioxide is used as the cathode material for four kinds of battery cells: Leclanché cells, magnesium-manganese dioxide cells, alkaline manganese dioxide cells and lithium dioxide primary cells.

Leclanché cells (zinc-carbon) remain most widely-used primary batteries because of their low cost and acceptable

TABLE XXXIV

TYPICAL CHEMICAL ANALYSIS OF 'FARADISER M' BATTERY GRADE CMD
(%)

	Typical Analysis
Mn	60.0
MnO_2	90.0
Pb	-
Co	0.0004
Ni	0.0005
Cu	0.0005
As	Traces
Mo	0.01
Sb	Traces
SO_4	0.36
Fe	0.01
NH_3	0.01
Na_2O	0.135
K_2O	0.065
CaO	0.105
Insol Hel	0.075
H_2O	2.25
pH (H_2O)	5.25
Particle Size	80% minus 44 microns

Source: Industrial Minerals, July, 1985.

TABLE XXXV

FORMULAE AND MANGANESE CONTENT OF MANGANESE CHEMICALS

CHEMICAL	FORMULA	(%) MANGANESE	MAIN END USES
Manganese acetate tetrahydrate	$Mn(C_2H_3O_2)_2 \cdot 4H_2O$	25	Oxidation catalyst.
Manganese borate			Ink drier, fire-retardant.
Manganese carbonate	$MnCO_3$		Natural or intermediate product in making manganese chloride, electrolytic manganese dioxide (EMD) and manganese metal, glass and ceramics; welding rods.
Manganese chelates			Fertilizers.
Manganese chloride	$MnCl_2$		Glass and ceramics, other chemicals.
Manganese ethylene bisdithiocarbamate (Maneb)	$(CH_2NHCSS)_2Mn$		Fungicide.
Manganese dioxide	MnO_2		Magnesium metallurgy; glass and ceramics; primary batteries.
Manganese gluconate	$Mn(C_6H_{11}O_7)_2 \cdot 3H_2O$		Vitamins.
Manganese hypophosphite			Removing sheen from nylon.
Manganese naphthenate			Paint additive and drier.
Manganese oxide	MnO		Animal foods, fertilizer, micro-nutrients, welding rods.
Manganese phosphate	$Mn(H_2PO_4)_2$		Rust proofing.
Manganese resinate			Varnish and paint.
Manganese sesquioxide	Mn_2O_3	69	Ferrites, semi conductors, thermisters and electronics parts.
Manganese sulphate	$MnSO_4$	27-28	Fertilizer micro-nutrients, other chemicals.
Manganese tetroxide	Mn_3O_4	70.6	Glass and ceramics, welding rods, coatings, welding fluxes, electronics.
Methylcyclopentadienyl manganese tricarbonyl (MMT)	$(CH_3C_5H_4Mn(CO)_3$		Anti-knock additive in gasoline.
Potassium permanganate	$KMnO_4$		Saccharine, oxidizing agent, disinfectant, pollution control.
Sodium manganese sulphate	$NaMnSO_4$		Fertilizer micro-nutrients.

(1) Kirk-Othmer's Encyclopedia of Chemical Technology, 3rd. Ed. and other Encyclopedias of Chemical Technology).

performance. Leclanché cells consist of a zinc anode, manganese dioxide cathode and an electrolyte of ammonium chloride and/or zinc chloride. Despite the introduction of competitive products such as the zinc alkaline cells, demand for Leclanché cells has grown by 10 per cent annually over the last decade. There are three types of Leclanché cells which require the use of manganese:

- General purpose cells: natural manganese dioxide ore is used as the cathode and is best adapted to low-rate discharge as the cost is low.
- Industrial heavy-duty cells: both EMD, or EMD mixed with natural ore, can be used as the cathode. These cells are used for heavy intermittent service in industrial applications.
- Zinc chloride cells: EMD is used for the cathode. These cells perform well in heavy intermittent applications and medium and heavy continuous discharge.

Magnesium-manganese dioxide cells use manganese dioxide mixed with acetylene black to provide conductivity with aqueous magnesium perchlorate as electrolyte. Their main application is in military equipment such as transceivers and standby equipment.

Alkaline manganese dioxide cells have the same zinc anode and manganese dioxide cathode as Leclanché cells but with potassium hydroxide electrolyte. EMD is used to obtain higher reactivity and capacity. Due to the great market penetration which portable electronic equipment (radios and cassette recorders) has achieved, demand for alkaline-manganese

dioxide cells has shown the most spectacular growth in the primary cell market.

Lithium-manganese dioxide cells require a specially prepared heat-treated form of manganese dioxide as the cathode material. Both flat and cylindrical versions of the cells are used in watches, cameras and calculators.

The consumption trend over the last ten years has favoured alkaline manganese dioxide batteries, primarily as a result of the micro electronics boom. More importantly, these cells have a higher energy capacity than zinc-carbon cells, up to ten times longer life, a longer storage life and higher leak resistance. In the early 1970's, Leclanché dry cells accounted for almost 90 per cent of western world sales of primary batteries. By 1985, it was estimated that alkaline batteries accounted for half the United States market and nearly 30 per cent of the United Kingdom and European markets.

As alkaline battery consumption has risen, the pattern of manganese consumption in batteries has altered significantly. Alkaline batteries principally use EMD or CMD, whereas Leclanché cells consume natural battery-grade ore or a mixture of natural and electrolytic manganese dioxide. Natural ores used in batteries are high grade pyrolusite ores containing 70 per cent to 85 per cent MnO_2.

World consumption is currently estimated at 200,000 tonnes. The supply of natural battery grade ores, however, has been depleted in the traditional producers, Ghana and

Gabon. But, at the same time, the higher performance requirements of modern alkaline batteries have stimulated the use of EMD and CMD.

World consumption of EMD was estimated at 140,000 tonnes in 1985. The rate of growth in consumption has apparently slowed from about 10 per cent per year up to 1980, to only around 3 per cent per year since then, as a result of the economic recession and the trend towards smaller, more compact batteries.

CMD has the advantages of lower initial capital investment, lower energy consumption and energy costs than EMD. The production cost is lower than EMD because the manufacturing process does not require electrolysis. Offsetting these positive factors is the 20 per cent to 30 per cent lower specific gravity of CMD compared with EMD, which leads to restricted energy density and shorter battery life. CMD is not generally used in heavy discharge applications such as alkaline batteries. Total CMD production capacity is 40,000 tonnes per year with consumption in Belgium and Japan.

Bricks and Tiles

The brick and tile industry requires the use of manganese for colouring purposes. Manganese is applied to face bricks by body staining, where it is added prior to extrusion in the pug mill, or by surface staining. Generally, natural manganese ore grading 70 - 88 per cent MnO_2 can be used, if

the high iron content offsets lower manganese content. Manganese chloride, manganese sulphate and pure manganese oxide are used for very special applications as they have prohibitively high cost. Both Canada and the United States have a small market for coarse grain manganese.

Agriculture

There are three uses of manganese in the agricultural sector: fertilizer, animal feed and fungicides. For fertilizer use, manganese is usually applied as manganese sulphate. Manganese sulphate is highly soluble, manganese oxide is only slightly water soluble but less expensive than manganese sulphate per unit of manganese. Recently, manganese oxysulphates, a combination of MnO and $MnSO_4$ containing 28 - 40 per cent Mn, have become popular for immediate release to soil at reasonable cost.

Animal feed requires manganese ore with 62 - 65 per cent Mn content, but not in manganese dioxide form which does not provide available manganese readily.

In fungicides, manganese ethylene bisdithiocarbonate (Maneb) prevents black rot, blight and mildew in vines, potatoes, tomatoes and fruit trees. The bulk of manganese sulphate demand in the United States is in fertilizer and livestock nutrients which account for around 80 per cent of demand; fungicides and herbicides have 20 per cent. Consumption of manganese in fungicides has fallen significantly since the residue has been found to be carcinogenic.

Manganese ores for agricultural use should have very low content of toxic elements such as arsenic.

Water Purification

Either as natural ground manganese ore or as potassium permanganate, manganese is used to treat drinking water and purify industrial and municipal waste water. In Canada, the Public Service Commission of Halifax and the Ontario Ministry of the Environment (Dufferin Creek Water Pollution Control plant at Pickering) use manganese for water purification.

The ores needed for water treatment contain over 75 per cent MnO_2 and the processed ores used could range up to five times the price of ordinary natural ores because of the large quantities of reject material. The world market is currently small, as lime is the chief chemical used in water treatment.

Potassium permanganate is used as an oxidizing agent in water treatment, mostly because it does not affect the taste of the treated water. For oilfield water it acts as a bactericide, removes dissolved iron and aids flocculation. Potassium permanganate is derived from pyrolusite ore containing 70 - 95 per cent MnO_2.

Hydrometallurgy

The two major applications for manganese in hydrometallurgy are uranium processing and electrolytic zinc.

Manganese dioxide is used as an oxidizing agent in the production of U_3O_8 (yellowcake) from uranium ore. Consumption has fallen from an estimated 0.4 million tpy in the late

1970's to about 0.1 - 0.15 million tpy currently. Uranium prices are currently depressed and no large new mining projects are underway. Moreover, both sodium chlorates and the ferrous leach system for uranium processing are eliminating the use of manganese. The ores needed for uranium processing are low grade and are used principally in the South African and Australian uranium industries.

Manganese dioxide is also applied in both the leaching and electrolysis stages in electrolytic zinc production. The ores used are high grade, around 75 - 80 per cent MnO_2.

Welding Fluxes

Strictly speaking, welding is a metallurgical application of manganese but the ore is used in ground form. Welding fluxes are involved in welding processes, where an arc provides the heating source, and in electro-slag welding. Several forms of manganese can be used:

- In coated electrodes, manganese metal, manganese dioxide and manganese carbonate are among the flux ingredients.
- In flux-cored electrodes, the manganese functions as a dioxidizing element in the form of ferromanganese.
- In submerged arc and electro-slag welding, natural manganese ores containing manganese oxide and manganese dioxide can be used, in contrast to covered and flux-cored electrode welding. The grades of manganese are generally in the 80 - 84 per cent MnO_2 range.

Currently, Groote Eylandt premium fines, selected for less than 0.4 per cent BaO, and Comilog are the principal suppliers of natural ores for welding fluxes.

Annual consumption levels of welding fluxes are dependent entirely on the steel industry. With the depressed state of the steel industry in the early 1980's, the growth potential for manganese flux demand is restrained. There is, however, one area of growth in flux-cored wires, as ferromanganese constitutes 30 - 40 per cent by weight of the wire. The best estimate of current world consumption of manganese in fluxes is about 80,000 - 150,000 tonnes per year in early 1985 (which includes ferromanganese).

Glass

Manganese provides three functions in glass manufacture: as a scavenger, a decolourizing agent and as a colourant. The main function is as a colourant to produce a range of colours from pink to purple to black. In Western Europe, manganese dioxide is added to iron to produce amber-coloured beer, cognac or wine bottles. The manganese ore usually contains 75 to 88 per cent MnO_2, ground to minus 50 mesh.

Manganese sulphate is added to glass to slow the extraction of salt from glass by alcohol in liquor bottles.

High purity manganese dioxide (99 per cent MnO_2) is also used in coloured lenses, filters and decorative structural glass both to decolour and to impart colour.

The glass market, however, is very small and was estimated at just over 5,000 tonnes per year, worldwide, in the late 1970's. The total volume consumed for glass purposes has now fallen because selenium has replaced manganese as a decolourizer in glass.

Ferrites

Ferrites are ferromagnetic ceramic materials made from metal oxides using highly-refined methods of ceramics technology. Ceramic magnets generally have an electrical resistivity ten times larger than metallic magnets. Although there are hard and soft ferrites (distinguished by the permanency of the magnetization process), the greater use is found for soft ferrites. The primary application is in the manufacture of receivers in television sets. The next most important application is in telecommunications.

Manganese ferrites are used as cores for conductors, low frequency and pulse transformers and as low energy conductors at low signal levels. The computer technology explosion of the last decade has produced the highest demand for manganese-zinc ferrites or square loop ferrites which can store megabits of information in high-speed digital components. Annual world consumption in soft ferrites is estimated at 12,000 tonnes of contained manganese at present. The United States accounts for roughly one-quarter of the world market for soft ferrites. The fastest growth in consumption, however, is in Japan with its increasing production of video tape recorders, office automation equipment and personal computers. Annual growth rate in Japanese soft ferrite consumption is over 10 per cent.

Specifications for natural manganese ores are high, 84 - 85 per cent MnO_2 and the Moroccan and Gabon ores are used.

For the higher performance soft ferrites used in computer and similar equipment, EMD, CMD or high purity Mn_3O_4 are preferred.

Other End-Use Sectors

Very small quantities of manganese are used in the following applications:

- Tumbling Media
- Pigments
- Paint Driers
- Sulphur Dioxide Removal
- Odour Control
- Sealants
- Phosphatizing

Tumbling media are small ceramic pieces (less than one inch in length) that are formed in the shape of triangles and rods. The principal use is to remove sharp edges from metal parts in a process called deburring which tumbles the ceramic pieces with the machined metal. Manganese dioxide is added to the basic compound alumina in order to lower the firing temperature and add weight to the body.

Very small amounts of manganese dioxide have been used by automotive manufacturers in the United Kingdom and Canada, as a pigment in undercoating formulations. Manganese dioxide has also been substituted for carbon black in printing ink.

Manganese was tested as a replacement for cobalt and lead paint driers in the United States recently. The tests proved unsuccessful but manganese still holds potential in

industrial paints for bridges and ship hulls.

In Japan, manganese dioxide is combined with sulphur dioxide to form manganese sulphate in the removal of sulphur dioxide from stack gases. When further combined with ammonia, it becomes ammonium sulphate for fertilizer use.

Potassium permanganate is used to control odours from paint factories, fuel processing plants, starch manufacture, fermenting operations and asphalt plants. An oxidation catalyst containing manganese dioxide has been developed to control odour of hydrocarbons, paints, resins and varnishes.

Manganese dioxide is also part of the catalyst system which provides oxygen that causes rubber to polymerize. Rubber-like sealants which are used in the seams of buildings and windows combine the main body of rubber with the catalyst.

Manganese phosphates may be used to prevent rust on metal surfaces and in treating metal surfaces to reduce wear. The major application is in the automotive industry.

The production of hydroquinone, used as a photographic developer, was an important user of manganese ore in the past, and also an important source of by-product manganese sulphate. There is no hydroquinone production in the western world that is now based on the manganese process.

RESULTS OF QUESTIONNAIRE SURVEY

BATTERIES

There are relatively few producers of alkaline dry cell batteries in North America and they are large, international companies, generally with centralized purchasing systems for their critical raw materials such as manganese.

The companies contacted for this assignment were:

Foote Mineral Co.
Kerr-McGee Chemical Corp.
ESB Materials, Division of RAYOVAC
Eveready Battery Co. Inc., Danbury, Ct.
Eveready Division of Ralston Purina, Toronto
Duracell Inc., Toronto
Gould Manufacturing Co., Toronto

All of the alkaline battery manufacturers contacted purchase both natural battery active ore and electrolytic manganese dioxide (EMD) and/or manufacture EMD for captive use.

Specifications for natural ores have tightened and the proportion of EMD used has increased as a reflection of the higher performance required of most types of battery that use manganese.

Natural Ores

Natural battery active ores are imported by the battery manufacturers and also by ESB Materials which supplies manganese materials to the United States battery industry. Manganese producers supplying the United States include

Gabon, Australia and Mexico, among others, and ESB currently is evaluating ore from Brazil.

Purchases are made essentially on a spot basis and prices are negotiated for each shipment.

Eveready, which purchases for its world wide operations from its Danbury, Ct. office, has a list of suppliers who can meet its specifications and, while specifications have tightened and certain sources have declined in importance, suppliers rarely lose their place on the list.

In Canada, Eveready purchases both natural ore and EMD for battery manufacture.

Prices for battery grade ores are perceived to have been stable or to have declined slightly in real terms over the past five years.

The cost of milled ore delivered to eastern Canada was estimated at Cdn$0.28 per pound for 1986.

Two of the companies approached, ESB Materials and Kerr-McGee, expressed interest in a potential North American source of manganese ore and both indicated, verbally, that they would be willing to test such a potential new ore.

EMD

Producers of EMD use metallurgical grade ore, and also ferromanganese fines in one instance. United States producers are Foote Mineral Co., Kerr-McGee Chemical Corp., ESB Materials, Chemetals and Eveready (formerly the Union Carbide business).

EMD is also imported from Japan (Toyo Soda, Mitsui Mining, Daiichi Carbon, Japan Metals & Chemicals Co.) and from Mexico (Cia. Minera Autlan).

In Canada, two battery manufacturers use EMD, Duracell Inc. and Eveready. There is no domestic production of EMD.

In contrast to the pattern for battery active ores, metallurgical grade ores for EMD production are purchased on annual contract basis. EMD is purchased under contracts of one or more years duration.

The EMD market in the United States is competitive and a new producer, Foote Mineral, entered the market at the end of 1985, having converted its manganese metal production facilities to EMD. All respondents agreed that EMD prices have fallen in real terms over the past five years.

One company which imports metallurgical ore estimated US$67.50 per short ton, delivered, for metallurgical fines from Australia; the same company is budgeting US$65.00 per short ton for 1987.

For 1986, the cost of high grade Japanese EMD delivered in eastern Canada was estimated at Cdn$1.00 per pound, or Cdn$0.94 for Mexican material.

BRICKS AND TILES

Manganese dioxide of very high grade is used by manufacturers as a colouring compound in the production of grey brick. The principal suppliers of manganese feed stock for the North American brick and tile Industry are American

Minerals Inc., Prince Manufacturing Inc., C-E Minerals and Foote Minerals. These companies comprise the major corporations in the North American manganese grinding industry. They import high grade manganese ores from Australia, Morocco and South Africa and finely grind the ores to increase surface area and degree of reactivity. A typical specification of manganese dioxide utilized by brick manufacturers in Canada, air-floated "Iminore" ores, is contained in Appendix I.

In the United States, there are a large number of brick manufacturers but none has a demand for manganese ores in excess of 1,000 tonnes per year. There are relatively few 'large' manufacturers of brick in Canada and the demands of these companies range from about 35 to 100 tonnes per year. The manganese-produced grey brick is a more expensive product which is utilized in structures designed to be architectually appealing, including hospitals, schools, shopping centres, museums and the like. As a result, demand fluctuates from year-to-year and is related to the total level of capital expenditure for such structures.

The manganese ores must contain from 75 to 85 per cent manganese dioxide and are ground such that 90 to 98 per cent pass a 325-mesh; i.e. they are air floated. Moroccan ores are considered the most suitable by North American brick and tile manufacturers. Other principal suppliers are Australia and South Africa, while Gabon, Brazil and Mexico are also acceptable sources of supply.

In addition, both Canadian and American brick and tile manufacturers utilize coarser grades of straight ground manganese ore (not manganese dioxide), in 20- 100-mesh granulations, to produce citadel brick, a red brick with a black fleck on the finished surface.

The North American brick and tile industry saw few technological advances between the 1950's and the 1980's. As a result, a large portion of the United States brick manufacturing facilities are now foreign owned. These interests, principally Australian and Spanish, have purchased a large number of United States corporations and are revising their technology and productive capacity. However, these changes in ownership are not expected significantly to influence the demand for manganese ore or manganese dioxide to be utilized in the production of bricks and tiles.

Demand for North America for these high grade manganese ores in 1986 totalled some 13,600 to 18,000 tonnes. Canadian requirements were estimated to be between 900 to 1,400 tonnes. (Companies contacted included L.E. Shaw, Brampton Brick, Canada Brick and IXL Industries Limited.) Canadian brick manufacturers purchase their requirements for manganese either directly from the American grinding industry (Brampton Brick - Prince Manufacturing) or through Canadian brokers/-suppliers of manganese dioxide (Canada Colours and Chemicals Ltd. - American Minerals Inc.). Canadian suppliers purchase to meet their requirements on the spot market.

Typical prices in 1986, f.o.b. plant, for Canadian brick manufacturers ranged from $1.90 to $2.10 per pound for manganese ores.

Two of the companies contacted, American Minerals and Prince Manufacturing, expressed an interest in evaluating and possibly participating in the development of the Woodstock ore bodies. Both indicated verbally that they would be prepared to discuss providing front-end capital in exchange for long term exclusive marketing agreements.

AGRICULTURE

Fertilizers

There are three principal suppliers of fertilizer manganese to the North American market:

Frit Industries
Eagle Pitcher Industries
Stoller Chemicals

A fourth company, Traylor Chemicals, declined to respond to the questionnaire and the extent of its activities is not known.

There are three dry manganese products that are incorporated into fertilizers:

- granular manganese sulphate
- granular manganese oxysulphate
- manganese oxide.

All three can be included in dry mixed or bulk blended fertilizers, with nitrogen, phosphorus and/or potash granular

products. Manganese oxide may also be incorporated during the granulation process for nitrogen and/or phosphorus products.

Manganese sulphate can be dissolved for use in liquid mixed fertilizers.

Manganese is used for liquid mixed or foliage spray fertilizers in the form of 'Techmangan', a spray dried, instantly soluble manganese sulphate product that leaves no residue on solution. Chelated manganese is also used in liquid fertilizers.

Frit Industries and Eagle Pitcher are the only major producers of the manganese sulphate; Frit Industries also produces agricultural manganese oxysulphate.

Manganese feedstock for the dry products are reduced manganese ore (manganous oxide), ferromanganese fines and manganiferous slags. Techmangan is now produced and marketed from Mexico, having previously been produced in the United States by Tennessee Eastman.

Prices are based on contained manganese, 60 per cent Mn basis, and for Frit Industries, at least, the relative prices of the feedstock materials noted above, determine the quantities of each purchased.

At the time of writing, reduced ore (manganous oxide) in bulk for production of, for example, manganese sulphate is US$0.12 per pound, 60 per cent contained manganese basis.

Feedstock materials are purchased from American Minerals, Chemetals and Foote Minerals in the case of reduced manganese

ore, and from Elkem in the case of ferromanganese fines.

Foote Minerals purchases premium fines from Groote Eylandt in Australia and these are sold at -100 mesh. In reflection of the requirements of its agricultural sector customers, Foote specifies low iron content in manganese ore, low heavy metal content, for example tungsten, and 0.01-0.02 per cent calcium. During 1986, premium fines were purchased at approximately US$77.00 per short ton, delivered; US$60.00 per short ton is budgeted for 1987.

By-product manganese sulphate from hydroquinone production was an important source of feedstock for the North American fertilizer industry in the 1970's and early 1980's. The only remaining supplier, Tennessee Eastman, converted to the diisopropyl benzene process for hydroquinone manufacture in 1986.

The annual North American market for manganese fertilizers has been estimated as follows (Frit Industries):

	Gross Tonnes
granular manganese sulphate	12,700
manganese oxysulphate	13,600-22,600
manganese oxide	13,600
Techmangan	13,600-18,100
	53,500-67,000

Respondents perceive the agricultural manganese market to be highly competitive. This is partly due to the severely depressed state of the North American fertilizer industry which, itself, is a result of overproduction of grains,

including soy beans, and partly due to the proliferation of low grade, but inexpensive, manganese oxysulphate. The loss of supply of by-product manganese sulphate appears to have been anticipated and under the current demand conditions the alternate sources of supply are more than adequate.

The principal crop to which manganese is regularly applied is soy beans. Tree fruits, especially citrus in the south-eastern United States, may also require manganese. Almost all other non-vegetable or horticultural crops, depending upon local soil conditions, may require manganese fertilizer on occasion.

Small quantities of manganese are also used in high value fertilizer products, such as those used for golf course and other intensively managed turf.

In Canada, soy beans are grown in Ontario on 6,000 to 7,000 acres.

Fungicides

The principal North American supplier of manganese fungicides, Rohm & Haas, has two manganese-containing products, Dithane M45 and Dikar. Both are manufactured outside North America, in France, Colombia, Brazil and India. The manganese feedstock is manganese sulphate.

Manganese fungicides are used on fruit, vegetable, grain and 'ornamental' crops.

In Canada, approximately 190 tonnes of contained manganese is applied as fungicide. Some 75 per cent of this is consumed

in Ontario and eastern provinces. Apple and potato crops account for the greater part of consumption.

WATER AND WASTE TREATMENT

Potassium permanganate is a powerful oxidizing agent manufactured by chemically oxidizing manganese ore to potassium manganate followed by liquid phase oxidation of the manganate to permanganate. This process requires finely ground premium grade manganese ores which are supplied from Morocco, South Africa or Australia. Carus Corporation has a capacity of approximately 13,600 tonnes annually. However, the total North American market in 1986 was approximately 6,400 to 7,300 tonnes; the Canadian demand is small, only some 180 to 270 tonnes annually.

The principal suppliers of potassium permanganate to the North American market are the United States, China and Spain with the world's largest producer, Carus Corporation, located in the United States.

Potassium permanganate is used in the treatment of potable and waste waters. It removes undesirable contaminants including iron, manganese and sulphides, as well as most taste and odour producing compounds. In addition, it inhibits bacterial and algicidal growth, and does not affect the natural taste of drinking water. It is also used in the treatment of waste and industrial waters to control odour, to remove sulphides, to destroy or minimize odours from sewage treatment plants, and has a wide range of uses in the

treatment of wastes from the pulp and paper, automobile manufacturing, metal treating, nuclear power generating and other industries.

North American production has declined over the past decade from some 13,600 tonnes to 7,250 tonnes annually, due largely to the loss of markets outside North America to producers in Spain, China, East Germany, India, Japan, Czechoslovakia and the USSR. However, there are growing market opportunities in North America in the fields of water and waste water treatment.

In 1986, the price of potassium permanganate was approximately $1.65 per pound. However, prices are customer volume and end use sensitive and during the last half of the year North American producers were forced to drop their prices to between $1.00 to 1.30 per pound to maintain markets being subjected to price competition from foreign suppliers.

HYDROQUINONE

The company contacted was Tennessee Eastman.

Hydroquinone can be produced by three methods, in one of which aniline is oxidized to quinone, in the presence of excess manganese dioxide.

Tennessee Eastman, division of Eastman Kodak in the United States, was the last producer in the western world to abandon the aniline process when it switched to the diisopropyl benzene process in 1986.

In the mid-1970's, Weiss estimated that 37,500 tonnes of manganese ore were consumed annually in the production of hydroquinone in the western world. This end use for manganese ore, generally 78-80 per cent MnO_2, has now entirely disappeared.

Manganese sulphate was a by-product of hydroquinone production by the aniline process and Tennessee Eastman was estimated to have produced 36,000 tonnes per year, largely for the fertilizer and animal feeds industries.

As noted above, present supply of manganese sulphate to the fertilizer industry in North America appears adequate to meet demand.

SEALANTS

The company contacted was Eagle Pitcher.

Eagle Pitcher produces manganese dioxide for use in sealants and insulating compounds. Manganese dioxide provides oxygen which causes the sealant to polymerize.

This end use requires high grade manganese dioxide, 84 per cent MnO_2, and the United States market is of the order of a few hundred tonnes per year.

PRICE OF MANGANESE ORE

Unlike base metals, manganese ores are not traded on a commodity exchange and there are no world market prices. There are three channels for ore sales: free market transactions, captive or tied market sales and barter arrangements. Free market transactions are estimated by UNCTAD to constitute 65 to 70 per cent of world sales and captive sales 15 to 20 per cent. Barter arrangements, which are a common practice in Eastern Europe, account for 15 per cent of world sales.

Free market sales generally are under annual contract with the final sales price arrived at through negotiations between the mining company and the consumer, usually between November of the previous year and May of the year of shipment. Prices for major contracts are revealed publicly and, in general, these set the price trends.

Prices published in trade journals, such as Metal Bulletin, reflect contracts already made. Although these prices reflect the manganese market, they do not provide a precise record of prices paid, due to the variables which affect price negotiations. These variables include the quantity, grade, delivery terms, chemical composition, physical properties and end-use of the ore, as well as freight, insurance and duties to be paid. Due to the bulky nature of the commodity, transport costs are an important

price determinant and, normally, sales are made on a c.i.f. basis.

Although manganese ore is consumed in metallurgical, chemical and battery industries, the sheer dominance of demand by the world iron and steel sector usually sets the trend in international ore prices.

The available price data for non-metallurgical grade manganese ores, battery and chemical are summarized in Tables XXXVI and XXXVII. These two series were used since they provide relatively long, consistently reported price series, compiled by Industrial Minerals. The Sterling price quotes reported by Industrial Minerals, were converted to the U.S. dollar equivalent, using the annual average Sterling-U.S. exchange rate for the respective years. In order to remove the effect of general price inflation from the nominal prices, the OECD (Europe) GNP deflators, for the relevant years, were used to deflate the manganese ore price series to a 1985 constant dollar basis.

Between 1970 and 1985, the long term price trend for battery grade ore showed three phases of development: 1970-early 1977, 1977-1980 and 1980-1985. In the first phase, nominal prices remained relatively stable between 1970 and 1974, but real prices fell precipitously from US$298-US$339/tonne, to US$188-US$210/tonne. There was a temporary surge in prices in 1974 and 1975, but real prices slumped back to the earlier levels in the following two years. The

TABLE XXXVI

EUROPEAN PRICES FOR BATTERY GRADE MANGANESE ORES

Unground, 78% - 85% MnO_2

C.I.F.

Date of Change	US $/tonne Nominal	Real 1985 $
1970	69.5 - 79.0	298 - 339
1971	71.0 - 80.5	284 - 322
January, 1972	72.5 - 82.5	271 - 308
September, 1972	65.0 - 72.5	243 - 271
1973	63.5 - 71.0	219 - 245
January, 1974	61.0 - 68.0	188 - 210
April, 1974	110 - 124	340 - 383
January, 1975	104 - 118	283 - 322
May, 1975	133 - 144	362 - 392
1976	108 - 117.5	267 - 290
January, 1977	105 - 113.5	234 - 253
March, 1977	145 - 154	324 - 344
December, 1977	134 - 154	299 - 344
January, 1978	148 - 169	300 - 342
1979	191 - 201	345 - 363
January, 1980	209 - 221	325 - 343
May, 1980	233 - 256	362 - 398
August, 1980	233 - 256	362 - 398
December, 1980	216 - 256	335 - 398
1981	189 - 223	257 - 303
January, 1982	189 - 193	234 - 239
June, 1982	219 - 236	271 - 292
1983	230 - 245	264 - 281
1984	230 - 245	246 - 262
1985	230 - 245	230 - 245
1986	230 - 245	

Source: Industrial Minerals.

TABLE XXXVII

EUROPEAN PRICES FOR CHEMICAL GRADE MANGANESE ORES

74% - 84% MnO_2

Bulk, C.I.F.

Date of Change	US $/tonne	
	Nominal	Real 1985 $
August, 1980	130-200	202-311
January, 1981	114 - 175	155 - 238
December, 1981	114 - 197	155 - 268
1982	98 - 170	121 - 211
January, 1983	85 - 164	97 - 188
November, 1983	85 - 137	97 - 157
1984	75 - 120	80 - 128
January, 1985	73 - 117	73 - 117
February, 1985	117 - 195	117 - 195

Source: Industrial Minerals.

1974-1975 price peak largely was attributed to the general commodity price boom of the mid-1970's. Additional factors contributing to the price increase in nominal terms were higher costs for freight, environmental and energy input costs and inflation (following the first OPEC price shock of 1973).

During the period 1977 to 1980, the advent of micro-electronic products, from automatic cameras to portable stereos, boosted the demand for longer lasting dry-cell batteries worldwide. Price for battery grade ore reflected the growth in demand and recorded a healthy real price gain of 57.3 per cent between early 1977 and 1980 (using the high range of the prices shown). Demand from dry cell manufacturers remained buoyant in the early 1980's, and nominal prices for battery grade ore rose between 1981 and 1983. Real prices in this period, however, were on a downward trend, with the high range in 1985 (US$245/tonne) being some 38.4 per cent below that of December, 1980 (US$398/tonne).

The price series available for chemical grade ores is shorter than for battery grade ores. The price trend for chemical grade ores, since 1980, has been decidedly negative as both nominal and real prices declined. The only significant rise in prices occurred in February, 1985, when prices increased from US$73 - US$117/tonne to US$117 - US$195/tonne, because of higher levels of activity in the ceramics, glass and chemical industries. Nonetheless, the high range for

chemical grade manganese ore prices in 1985 (US$195/tonne) was 37 per cent lower in real terms than the US$311/tonne achieved in 1980.

HISTORICAL DEMAND, SUPPLY AND PRICE

In general, the predominance of the world steel sector consumption of natural manganese ores sets the trend for the price of manganese ores in other end uses.

Table XXXVIII shows the relative rate of change in real prices for metallurgical, battery and chemical manganese ores between 1975 and 1985. The depressed level of steel sector demand for manganese and the world over-capacity in ore supply led to a 7.7 per cent average annual rate of decline in the real price for metallurgical grade ores between 1975 and 1980. By contrast, rapid gains in demand for battery grade ores by the battery manufacturers contributed to a 0.3 per cent average annual rate of increase in the real price of battery grade ores in the same time period.

During the 1980's, however, battery manufacturers increased their consumption of elelctrolytic manganese dioxide (EMD) and synthetic chemical manganese dioxide (CMD) in the production of high performance alkaline cells. The real price for battery grade ores reversed its mid-1970's trend and averaged an annual rate of decline of 9.2 per cent.

Meanwhile, metallurgical ore demand worldwide continued its slump and registered a comparatively faster rate of decline in its real price, at over 11 per cent per annum.

TABLE XXXVIII

COMPARATIVE SUMMARY OF REAL PRICE MOVEMENTS

IN MANGANESE ORES

	Average Annual Rate of Change (%)		
	Metallurgical Manganese Ores (cif London)	Battery Grade Ores (cif Europe)	Chemical Grade Ores (cif Europe)
1975 - 1980	- 7.7	+ 0.3	N/A
1980 - 1985	-11.4	- 9.2	- 8.9
1975 - 1985	- 9.5	- 4.6	N/A

N/A - Not Available

than the premium grade battery ores.

Although the real price for chemical grade ores also fell in the 1980-1985 period, a price rebound in 1985 led to only an average annual rate of decline of 8.9 per cent, the slowest rate of decline among the three grades of manganese ores.

FORECAST OF MANGANESE ORE SUPPLY AND DEMAND TO 2000

SUPPLY FORECAST

Existing Producers

Recent production history and the supply forecast for those existing producers of manganese ore which have significant output of non-metallurgical grades are shown in Table XXXIX. With the exception of Morocco, Greece, Thailand and Indonesia, the production of metallurgical grade ore far outweighs that of the non-metallurgical grades and the production forecast, therefore, reflects primarily the expected output destined for the iron and steel industry. Production of chemical grade manganese ore in South Africa is consumed domestically. South African output of metallurgical ore is not shown in Table XXXIX.

Production of non-metallurgical, non-battery grades from other countries is expected to remain stable through the forecast period. Gabon is the largest with some 100,000 tonnes per year of output. During the forecast period to the year 2000, one major producer of non-metallurgical manganese ore, Morocco, is expected to cease operations due to exhaustion of reserves. The significance of the probable closure, around 1990, lies in the fact that Morocco currently supplies some of the highest grade material to the non-metallurgical and non-battery sectors, principally to markets in Europe.

TABLE XXXIX

TOTAL MANGANESE ORE PRODUCTION AND PRODUCTION FORECAST

(thousand tonnes gross weight)

	1978	1979	1980	1981	1982	1983	1984	1985	1990	1995	2000
Australia (1)	1,249	1,724	2,020	1,449	1,127	1,370	1,829	1,989	2,500	2,500	3,000
Brazil	1,633	2,259	2,282	2,042	2,341	2,002	2,693	2,700	3,000	4,000	4,000
ICOMI (2)	1,173	1,439	2,044	1,363	1,592	1,392	1,500	1,600			
CVRD (3)	-	-	-	-	-	-	-	1,000			
Gabon (4)	1,661	2,300	2,146	1,488	1,512	1,857	2,119	2,351	2,500	3,000	3,500
Ghana (5)	316	272	249	223	160	173	269	307	450	450	450
Greece (6)	7	6	6	6	5	5	5	5	5	5	5
Indonesia (7)	6	6	4	3	18	8	8	8	10	10	10
Mexico (8)	523	493	447	578	509	350	476	464	500	500	500
Morocco (9)	126	135	132	110	96	74	57	44	20	-	-
South Africa (10) chemical grade	137	229	367	341	334	256	192		200	200	200
Thailand (11)	72	35	54	11	8	6	9	8	10	10	10

(1) 1984: first production of battery grade. 30,000 tpy planned.
(2) 1% of production is non-metallurgical grade. Figure included in Brazil total.
(3) 1983: 4,000 t battery grade. 1985: 15,000 t battery grade. Figure included in Brazil total.
(4) 1984: 74,000 t non-metallurgical grade. 1985: 65,000 t non-metallurgical.
(5) Approximately 10,000 tpy battery grade.
(6) Virtually all non-metallurgical.
(7) Virtually all chemical/battery grades; battery grade consumed domestically.
(8) 1983: 35,000 t battery grade. 1984: 21,000 t battery grade.
(9) Virtually all non-metallurgical grades.
(10) Chemical grade not exported.
(11) 1984: 6,000 t battery grade, all consumed domestically.

Potential for Expansion

The countries with the potential to offset and to exceed the decline in production of high grade non-metallurgical ore from Morocco are Australia and Brazil (CVRD). Australia entered the market with approximately 150,000 tonnes per year in the early 1980's. CVRD has established a marketing network and is expected to sell significant quantities of natural manganese dioxide ores. The older major Brazilian producer, ICOMI, has non-metallurgical output of approximately 16,000 tonnes per year. Total reserves are diminishing but are sufficient at current production rates to cover the forecast period.

Natural battery active ores are produced in all of the countries shown in Table XXXIX except Morocco. The quantities are relatively small, although for some producers, such as Greece, Indonesia and Thailand, the battery grades account for almost all of the output. Countries expected to increase production of battery grade ores are Australia, Brazil and Mexico. Australia plans output of 30,000 tonnes per year, having started production of battery grade in 1984. Mexico produced over 35,000 tonnes of battery grade ore in 1983. Production of battery grades is expected to remain stable in other countries. Ghana faces declining reserves of high grade battery oxide ore and plans to convert carbonate ore to battery manganese dioxide.

Most EMD production capacity in 1986 was located outside

manganese ore producing countries and in the hands of non-ore producing companies. The two exceptions in 1986 were the Toyo Soda plant in Greece and the Delta plant in South Africa. Pilot EMD facilities are operating in Australia and Mexico, operated by Groote Eylandt and Cia. Minera Autlan, respectively.

Reserve Position

With the exception of Morocco, the reserve position of most producers of non-metallurgical manganese is adequate at current production levels. In Ghana, measures have been taken to upgrade reserves of carbonate ores. The reserve position of producers relatively new to the non-metallurgical market, Australia and Brazil, appears more than sufficient to offset declines elsewhere.

The over capacity of metallurgical manganese ore, resulting from depressed demand in the steel sector, will also affect supply of manganese for non-metallurgical purposes, since for a number of end uses, metallurgical grades are acceptable.

Finally, the circumstances which would encourage production from a new producer, such as at Woodstock, New Brunswick, would necessarily encourage expansion from existing producers.

New Producers

The number of potential new producers of manganese, whether for metallurgical or non-metallurgical end uses, is

small and is far outweighed in significance by the on-going development of the Carajas deposits by CVRD in Brazil. None of the projects mentioned below has been included in the supply forecast.

All of the notable new or potential projects that have been identified are located in Africa. A small mine and grinding plant was planned for start-up in 1985 in the Ivory Coast to serve an alkaline battery plant operated by the local Union Carbide subsidiary. The government of the Ivory Coast also has investigated the possibility of developing deposits grading 44 per cent and 47 per cent manganese.

In Burkina Faso (formerly Upper Volta), Cie. Minière du Kiere (Comiki) was formed in 1981 for the production of 20,000 to 25,000 tonnes per year of manganese ore, of which around 10,000 tonnes per year would be used for local battery manufacture. Of longer term significance is the start of construction, in 1985, of the 320-kilometer Ougadougou-Tambao railway link which would open up the manganese deposits at Tambao in the north of the country. Reserves of oxide ore reportedly amount to 13.3 million tonnes, grading 50-55 per cent manganese. The ore would primarily be used for metallurgical purposes.

Zaire was formerly an important source of manganese ore but, with the closure of the Benguela railway in 1975, closure of the mines followed in 1977. The operating company, Sté. Minière de Kisenge Manganese, reportedly plans

construction of an EMD plant and a battery plant. Reopening of the railway would provide the opportunity for production of non-metallurgical grade material.

DEMAND FORECAST

Forecast Methodology

The basic forecast methodology for non-metallurgical manganese ore demand is similar to the approach used in forecasting the world steel sector's demand for metallurgical manganese ores; i.e. a derived demand which brings together the growth potential of the various end-use markets, material substitution and/or conservation trends, and the development of new products. The demand forecast will consist of the industrialized world, developing countries and the Centrally Planned Economies between 1985 and 2000.

Probable Changes in Demand in End-Use Sectors

This section reviews the impact that known technical research, new products and market development will have on the major non-metallurgical manganese end-use industries in the world over the period 1985 to 2000.

Batteries

Following the micro-electronics boom of the late 1970's, the battery consuming markets of calculators, electronic games, Walkman units, video equipment etc. have settled into a mature phase of the industry's development. Therefore, battery demand growth is expected to experience a more modest period of growth than compared to the relatively

rapid pace of development of the last decade. Consumers' demand for longer life batteries has encouraged the development of zinc air batteries and lithium-sulphur dioxide cells. Zinc air batteries enjoy a number of advantages over alkaline-manganese dioxide batteries, including:

- the highest energy density of any battery yet developed;
- a shelf life of up to four years when sealed; and
- constant power output.

Zinc air batteries are expected to erode some market share for alkaline-manganese dioxide batteries in areas such as hearing aids, watches, telecommunication and medical equipment.

Lithium-sulphur dioxide cells use lithium as the negative electrode. Re-chargeable lithium batteries and non-chargeable lithium batteries are expected to penetrate the traditional markets for manganese-containing batteries.

Bricks and Tiles

Although no substitutes are expected for manganese in the colouring and staining of bricks and tiles, the market demand for bricks will continue to be affected by architectural design and the level of construction activity. The level of construction activity in the industrialized world is expected to be heavily influenced by the moderate growth trend in population. Although population growth in developing countries is expected to exceed the anticipated

rate of growth in industrialized countries, the demand for bricks and tiles in housing construction will be constrained by its relatively higher cost and the large rural population base.

Agriculture

Fertilizer and livestock nutrients account for 80 per cent of manganese sulphate demand in the United States agricultural market, with the remaining 20 per cent used in fungicides and herbicides. The current phase of restructuring the farming sector in both the United States and Europe presents a major obstacle towards advances in fertilizer manganese consumption. Fungicide demand for manganese will continue to decline following the discovery that residues in Maneb are carcinogenic.

Hydrometallurgy

In uranium processing, manganese dioxide acts as an oxidizing agent but its use is largely confined to uranium producing countries where manganese is located nearby, i.e. Australia and South Africa. Most uranium producers apply the ferrous leach system for uranium processing which does not use manganese ore.

Manganese consumption in the electrolytic zinc process will continue to depend on the future demand of zinc metal which itself is faced with material substitution in the final end uses.

Welding Fluxes

The overall demand for welding fluxes fluctuates with the business conditions in the steel industry. Some companies have turned to synthetic hausmannite (Mn_3O_4) produced in tunnel kilns because, in the past, there have been difficulties in guaranteeing supply of natural manganese ore. However, synthetic hausmannite is about twice the price of natural ore.

Hydroquinone

The production of hydroquinone for photographic developing, using the manganese route, came to an end in 1986. An alternative process based on diisopropyl benzene is now the industry standard as a more cost efficient method in developing photos.

Glass

Manganese ore consumption as a colourant or a decolouriser in the glass industry is diminishing. The industry has replaced manganese with selenium and zinc cyanate which are much easier to handle. Manganese use is now concentrated in the cheap end of the ornamental glass market and some MnO_2 is still used in specialty glass.

Demand Outlook in Steel

The demand for manganese ores in the steel sector, which accounts for 90 per cent of total world manganese ore consumption, will undoubtedly affect the non-metallurgical end uses as well. The two areas that would have the greatest impact are:

1. Supply: the general decline in demand for manganese in metallurgical applications and the over-capacity in manganese ore production has resulted in producers of traditional metallurgical manganese ores seeking markets in the premium non-metallurgical sectors.

2. Price: as more metallurgical grade ores are competing within a smaller market base, prices in nominal and real terms have fallen rapidly in sympathy.

The outlook for steel sector demand for manganese between 1985 and 2000 is influenced by the following factors:

- the expected slower growth in steel consumption and production; and

- changing steel production technology.

World steel consumption between 1985 and 2000 is expected to grow at an average rate of 1.5 per cent per annum, largely due to the falling intensity of steel use in the industrialized world and a shift in investment towards less steel-consuming equipment from high steel-consuming equipment. Following the rapid expansion of steel making capacity in the developing countries during the last decade, steel produced in the developing world is expected to account for a growing share of the world steel market. The relatively sluggish growth in steel consumption will ultimately affect the steel producers' overall demand for raw materials, including manganese.

Due to the slow growth expected in steel production, the increased use of continuous casting methods and technological developments in the uses of manganese, world manganese demand is expected to increase at about 1 per cent per year.

In contrast to the information on metallurgical manganese ores, there are no time-series consumption data for total world demand of non-metallurgical ores by each end use category. The only two exceptions are the United States and Canada. Therefore, the demand projections rely heavily on the most current data available in North America.

The demand forecast will concentrate on the three most important industries which constitute the majority of non-metallurgical manganese ore consumption: batteries, chemicals and bricks and tiles. Projections made according to the North American experience will be used as a base from which to derive the forecast of manganese ore consumption. Finally, the pattern of non-metallurgical manganese consumption in North America is judgmentally adjusted to present the forecast on the world trend in the individual end-use industries.

Demand Outlook to 2000

Battery Production

The United States Bureau of Mines (USBM) has found no good statistical correlation of this end use with any of the available economic indicators. This is primarily due to the fact that, in large part, battery consumption is a replacement demand which is not subject to changes in the business cycle. In other words, unlike items such as housing and autos where the total stock fluctuates according to general business conditions, new batteries will be purchased

whenever old cells fail, regardless of the rate of change in the economy as a whole. Battery demand in battery-operated equipment is also price-inelastic, i.e. batteries will be consumed as long as their energy content is needed to operate the existing stock of electronic equipment.

In the last ten years (1975 to 1985), North America (and the world in general) has witnessed an actual upward shift in the demand curve for batteries, due to the introduction of a whole new generation of products which require the use of batteries. The end use markets, however, have entered a mature phase of development, and the growth in demand for batteries in micro-electronics equipment is expected to be more stable in future. However, this will remain a growth market.

In the United States, battery industry consumption of manganese ores increased from an average rate of growth of 1.2 per cent per annum between 1975 and 1980 to 1.8 per cent per annum between 1980 and 1985. The anticipated growth rate in manganese ore demand from the relatively high base in 1985 will be constrained by the growing demand for new battery systems which would accelerate the penetration into the traditional alkaline-manganese dioxide battery market. The overall growth in battery industry demand for manganese ores in the United States is expected to be 1.5 to 2.0 per cent per annum, or from 35,500 tonnes in 1985 to 44,300 tonnes by the year 2000 based on the low end of our forecast range. (See Table XL).

TABLE XL

UNITED STATES CONSUMPTION OF NON-METALLURGICAL

MANGANESE ORES : 1985 - 2000

(tonnes)

FORECAST

End-Use	1975	1980	1985[1]	1990	1985	2000	Average Annual Rate of Change (%) 1975-80	1980-85	1985-2000	
Battery	14,000	15,000	35,500	38,200	41,200	44,300	1.4	18.8	1.5	2.0
Chemical	47,000	45,000	20,000	16,300	13,300	11,000	-0.9	-15.0	-4.0	-6.0
Others	182,000	144,000	154,500	133.300	117,500	99,700	-4.6	1.4	-2.9	-4.0
Total	243,000	232,000	210,000	187,800	172,000	155,000	-0.9	-2.0	-2.0	-3.8

(1) United States Bureau of Mines.

Forecast by Economics Practice, The Coopers & Lybrand Consulting Group.

For the rest of the western world, Industrial Minerals' estimate of manganese consumption in batteries was 250,000 tonnes in 1985. The newly industrializing countries such as South Korea, Taiwan, Singapore, Thailand, and Brazil, are expected to record strong growth in consumption of consumer goods including electronic goods within the forecast period. Therefore, overall growth in battery grade ore consumption is expected to be 2 to 3 per cent per annum to the year 2000. Based on the low end of the forecast range, total forecast amount is 336,500 tonnes or 2.1 per cent of the forecast western world consumption of all manganese ores by the year 2000.

Chemicals

There is no good fit statistically of this particular end-use with economic indicators in the United States. While real economic output has increased in the United States since 1975, chemical industry use of manganese ores fell 57.6 per cent between 1975 and 1985. Market penetration by imports and the reduced demand for fertilizers in the weak agricultural sector have reduced overall demand for manganese based chemicals. The deteriorating competitive position of United States chemical producers and rising imports is expected to reduce United States manganese consumption in chemical industries from 20,000 tonnes in 1985 to 11,000 tonnes by the year 2000 at the low end of our forecast range. No estimate of western world consumption is available for forecasting purposes.

Bricks and Tiles

The consumption of manganese as a colouring agent for bricks and tiles depends on the general level of construction activity in the country but, more importantly, on the changing attitudes of architects and homeowners towards decorative bricks. Total world consumption of manganese in bricks and tiles is estimated at 100,000 tonnes per annum or 0.6 per cent of all manganese ores consumed. The popularity of black facing bricks reportedly has decreased markedly particularly in the industrialized world thus far in the 1980's. This downward trend is forecast to continue. By the year 2000, total world manganese consumption is expected to reach only 74,000 tonnes. This is equivalent to a 2 per cent annual rate of decline.

Other End Uses

The demand for soft ferrites in telecommunication, personal computers and electronic entertainment products is expected to continue to grow at a strong pace. Overall world demand for ferrites will be dominated by Japan and the United States where consumption of soft ferrite magnets has been increasing at a rate of 10 per cent per annum during the 1980's.

Although the expected growth in demand for manganese used in ferrites is healthy, only relatively minor quantities are consumed. In the mid-1980's, the industry estimate for world manganese consumption in ferrites is about 12,000

tonnes per year. Between 1985 and the year 2000, consumption of manganese in ferrites is projected to increase by 8 per cent per annum to reach 38,000 tonnes by the year 2000. This forecast reflects the recent capacity expansions in ferrite production in Japan and Belgium.

In the industrialized world, government legislation towards water purity is becoming increasingly stringent. This implies a healthy future for the use of manganese dioxide in water treatment. Between 1985 and 1990, the demand for industrial water treatment chemicals is forecast to grow by 4 per cent per annum in the United Kingdom alone. Although no estimates for world consumption of manganese in water purification are available, the market is expected to expand steadily within the forecast period 1985 to the year 2000.

Despite the problem of data shortage for many of the end-uses of non-metallurgical manganese ores, some implications in the future consumption trend can be drawn from the previous qualitative analysis. The rate of growth in demand for manganese in the largest non-metallurgical end-use market for batteries is expected to moderate from the 1975-1985 experience. In the minor applications, growing optimism can be found for manganese consumption in ferrites, welding fluxes and water purification. Offsetting the areas of anticipated growth will be declining manganese consumption in chemicals, bricks and tiles, agriculture, glass colouring and hydrometallurgy.

Table XLI shows forecast total manganese ore consumption to the year 2000, with the forecast volume based on the low end of the forecast range. Overall non-metallurgical manganese demand is expected to increase only slightly from the estimated levels in the mid-1980's by the year 2000. The share of non-metallurgical manganese as a percent of total western world manganese consumption could increase slightly, largely because metallurgical ore consumption growth is forecast to be nearly static.

SUPPLY - DEMAND BALANCE

As noted in the introductory section of this report, statistics on manganese consumption are sparse. There is no time series of total world manganese consumption to compare with total manganese ore production.

World manganese ore consumption, for all uses, is forecast in this study to increase at a modest rate to reach 24.8 million tonnes in 1990, 26.2 million tonnes in 1995 and 27.8 million tonnes in the year 2000. World manganese ore production historically has exceeded 26 million tonnes. The additional 1.6 million tonnes required to meet forecast demand in the year 2000 is expected to be met without difficulty through incremental expansion at existing mines, such as those in Brazil and Australia.

Given the substitution that has already occurred for traditional non-metallurgical grades of manganese ore by metallurgical ore, it is anticipated that the requirements of

TABLE XLI

FORECAST MANGANESE ORE CONSUMPTION (ALL USES)
(million tonnes)

	1983[1]	1990	1995	2000	Average Annual Rate of Change (1983 - 2000) (%)
Industrialized World	7.2	7.5	7.6	7.8	0.5-1.0
Developing Countries	5.0	6.1	7.1	8.3	3.0-3.2
Socialist Countries	10.9	11.3	11.6	11.9	0.5-0.9
Total	23.2	24.9	26.3	28.0	1.1-1.5

(1) Mining Magazine estimate.

Forecast by Economics Practice, The Coopers & Lybrand Consulting Group.

the non-metallurgical sector, worldwide, will be met adequately from within the existing production base. It is noteworthy that although it is in the battery sector that positive growth in demand is anticipated, in the United States metallurgical ores and EMD have already replaced some demand for natural battery active ores.

In conclusion, it is not anticipated that changes in supply and demand over the period to the year 2000 will result in severe or prolonged supply shortage. It is considered unlikely that events will take place that would render economic low grade manganese ores such as those at Woodstock, New Brunswick.

Influence of New Technology on Supply

There are no manganese deposits being mined at present with grades as low as Woodstock. Therefore, the development of the Woodstock deposit will require the implementation of new mineral processing technology. Should an innovative processing system, such as heap leaching, be utilized, the result could be the rapid development of other low grade deposits. A large number of United States deposits, in particular, could be developed using the same technology. Thus, any advantage which a Canadian source may have over African or Central/South American sources in the United States market could disappear.

Examples of United States deposits in this category include the Hardshell Mine, Arizona, with 5.9 million tonnes

at 15 per cent Mn; Sunnyside Mine, Colorado, with 24.9 million tonnes at 10 per cent Mn; North Aroostook district, Maine, with 63 million tonnes at 9.6 per cent Mn; Maple Mountain - Hovey Moutain, Maine, with 260 million tonnes at 8.9 per cent Mn. Other similar deposits exist in Minnesota, Montana, and Nevada. The Maine deposits, in particular, would pose a threat to the continuing competitiveness of any development at Woodstock, a factor which could increase with United States protectionism.

The possible mining of deep sea nodules is an additional factor which must be considered. Although manganese is only a by-product of proposed recovery systems, the material produced would be high grade and in large quantities. It is considered unlikely that development of deep sea nodules will take place in the present century, in the absence of a major change in the supply-demand outlook for the principal metals, nickel and copper.

Influence of Potential Political Events

Manganese is one of the most important of the so-called strategic materials due to its pervasive role in the western economies, the relatively few major producers (including South Africa) and the lack of substitute materials for steel-making. Security of supply of manganese ore has been a concern, therefore, of the United States in particular, and of Japan and West Europe.

The non-metallurgical applications of manganese cover a

wide range of products but, with the exception of batteries, should not be considered as strategic. Again, with the exception of alkaline batteries, there are substitute materials for many of the non-metallurgical applications of manganese.

Concerns over security of supply and possible supply disruption of mineral commodities tend to centre on the predominance of production in southern Africa and the Socialist bloc. In the case of non-metallurgical manganese, while the African continent provides a significant proportion of total supply, South Africa itself contributes virtually no non-metallurgical manganese to international trade. Exports of non-metallurgical manganese from the Socialist bloc are not believed to be of such magnitude that the loss of this supply would cause major problems to western consumers.

In counter-balance to supply from southern Africa and the Socialist bloc are the producers in Brazil and Australia. These have well established and stable mineral trade links with a large number of importing nations.

It is considered unlikely that political events would cause serious and prolonged supply disruption to non-metallurgical manganese. It is unlikely that such supply disruption, alone, would justify the development of the Woodstock manganese deposits.

Influence of Currency Fluctuations

The strength of the United States dollar against the

currencies of many other mineral producing nations has had a profound effect on the relative competitiveness of the mining industries of different countries. In general, the Canadian dollar has shown similar strength against other currencies. The decline, since the fall of 1985, in the strength of the United States dollar has been principally against the currencies of the industrialized nations.

The effect has been to increase the local currency earnings of the mining industries in many developing countries, although United States dollar based prices have been static or have declined in real terms through the 1980's. Among manganese producers, the South African rand has continued to remain weak against the United States dollar, as has, to a lesser extent, the Australian dollar.

Conversely, the relative strength of the United States dollar, and its Canadian counterpart, increases the cost of mining in North America (all else being equal) and, thereby, reduces the attractiveness of new mining projects compared with those in developing countries.

OPPORTUNITIES AND MARKETING STRATEGIES FOR WOODSTOCK MANGANESE ORES

THE WOODSTOCK MANGANESE DEPOSITS

The Woodstock manganese deposits are located approximately 8 kilometers west of Woodstock in southwest New Brunswick, less than 20 kilometers by road from Houlton, Maine.

The deposits are located in an area of gently rolling semi-wooded farmland and are accessible by several all-season roads from Woodstock. A branch line of the Canadian National Railway formerly crossed the property.

First discovered in 1836, the deposits were used between 1848 and 1884 as a source of iron ore, mostly to produce armour plating for the Royal Navy. For nearly sixty years nothing further was done on the property, until 1943 when, prompted by war materials demand, Noranda conducted flotation tests to improve the low grade ore. The work was unsuccessful. Subsequent attempts to develop the property have been made by Fundy Bay Copper Mines Ltd., Stratmat Ltd. and Mandate Refining Ltd. Most of the ground is currently held by Maritime Resources Research Ltd.

Likely Grade of Manganese Ore

There are six deposits in the area with estimated reserves of 175 million tonnes at 9 per cent Mn. Those reserves are contained in the six deposits as follows:

Plymouth	- 46 million tonnes @	10% Mn
N. Hartford	- 45 million tonnes @	8% Mn
S. Hartford	- 45 million tonnes @	8% Mn
Moody Hill	- 9 million tonnes @	9-1/2% Mn
Iron Ore Hill	- 22 million tonnes @	10% Mn
Sharpe Hill	- 7 million tonnes @	9% Mn

The ore occurs within both an oxide and a carbonate facies. The oxide facies consists of interbedded red ferruginous slate and banded manganiferous hematite.

The carbonate facies consists of grey-green siliceous carbonate rocks. The facies is laminated with manganese carbonate occurring in one of the couplets.

Both facies occur together within all the deposits, but usually one facies is dominant. Thus, the Plymouth and North Hartford deposits are dominated by carbonate facies rocks and the South Hartford deposit by oxide facies.

The most abundant manganese minerals are braunite and rhodochrosite.

In addition to the six deposits in the immediate vicinity of Woodstock, there are other deposits in the region, notably those at Glassville, 38 kilometers northeast of Woodstock. The deposits are similar to the Woodstock deposits insofar as grades seldom exceed 10 per cent Mn. One of the prospects, south of Glassville, has been estimated to contain more than 450,000 tonnes.

Processing of Woodstock Manganese Resources

A major obstacle preventing development of the Woodstock deposits is the lack of a cost effective method of upgrading

the deposits. Three characteristics in particular pose problems:

a) low grade of the material
b) very fine texture of the manganese
c) intimate association of the iron and manganese

A study is currently underway by Witteck Development Inc., on behalf of the federal government, to investigate possible processing technology. Preliminary results to date indicate that the manganese can be put into solution. Two possible conceptual flow sheets have been identified. These involve the production of manganese sulphate and the production of manganese hydroxide which can be calcined to manganese dioxide. Electrolytic manganese dioxide is unattractive at the present time because of the high costs of power in New Brunswick.

MARKET OPPORTUNITIES

The opportunities for the marketing of manganese ore from the Woodstock, New Brunswick deposits are limited, due to the low grade of the material, around 10 per cent Mn compared with other developed manganese resources around the world which grade at least 30 per cent Mn and up to 55 per cent Mn.

As has been shown in this report, the non-metallurgical uses of manganese are divided roughly between those which require natural manganese ores and those which require manganese chemicals, for which the ores are the starting materials. With the exception only of natural ores used in uranium processing, all of the non-metallurgical applications

for natural manganese ores require high grade material and/or high manganese dioxide content. The Woodstock ores do not meet these requirements.

In recognition of the need to upgrade the Woodstock material, some processes are being tested by Witteck Development Inc. and it is understood that manganese sulphate and manganese dioxide, possibly, could be produced: the manganese dioxide would not be produced electrolytically, but by a chemical process. There are no data available at the time of writing in respect of likely typical analyses for these manganese products from the Woodstock deposits.

There are obvious attractions in a Canadian source of manganese chemicals for the domestic market. As shown elsewhere in this report, however, the total Canadian market for non-metallurgical manganese in all forms ranges between 5,000 and 10,000 tonnes per year. Th quantity of manganese that, potentially, could be marketed from Woodstock may not justify the capital investment required for development.

From the analysis carried out for this assignment, there is some, limited, potential in the market for agricultural manganese. This is for four reasons:

- it appears technically possible to produce manganese sulphate from the Woodstock manganese deposits;
- there is a small Canadian market for agricultural manganese sulphate that presently is served entirely by imports;
- the buyers of agricultural manganese sulphate are the fertilizer blenders and distributors who have price as their principal purchase criterion.

- the agricultural manganese market is not dominated by the major North American importers/grinders/-processors of manganese ores.

Currently the agricultural manganese market is understood to be highly competitive due to the supply of manganese oxysulphate which is relatively inexpensive compared to manganese sulphate.

Production of manganese dioxide may also be possible from the Woodstock deposits. In Canada and the United States the marketing of manganese dioxide is dominated by a few companies involved in the import and processing of natural ores or involved in the battery industry. Even to serve the Canadian market, it is likely that 'independent' production would meet with stiff competition from the existing suppliers.

PRODUCER-CONSUMER RELATIONSHIPS

In the case of supply of agricultural manganese sulphate, the relationship between producer and consumer would be relatively straight forward. Purchasing would be based on the customer's anticipated demand over the year ahead, with prices negotiated on the basis of a list price. It is general, in the supply of mineral commodities for industrial uses, for a working relationship to be built up between producer and consumer, whereby the producer responds to the technical requirements of the consumer which, in turn, reflect changing patterns of demand in the market.

For the supply of manganese dioxide, with the possible exception only of consumers in the zinc industry, the present

dominance of a few major companies suggests that a new producer would have to sell to one of those companies in order to benefit from its marketing network, rather than competing against it.

MARKET PENETRATION AND ACCESS STRATEGY

Two companies involved in the battery industry expressed interest in a potential source of natural manganese ore in North America and both offered verbally to examine the Woodstock material. These companies probably would be willing to examine the untreated ore and express opinion as to how it might be upgraded to meet their requirements, and to look at samples of manganese dioxide for their purposes.

Two more companies expressed tentative interest in backward integration into manganese ore supply to complement their heavy involvement in importing, processing and marketing.

It is suggested that an approach be made to these companies in order to discuss potentially marketable products and the processes whereby they could be manufactured.

CONCLUSIONS

Although there has been a traditional division of manganese ores into metallurgical and non-metallurgical grades, or into metallurgical, battery and chemical grades, these categories are almost meaningless in terms of actual usage and trade. Many manganese ores, and particularly the high grade ores, can be used for both metallurgical (steel industry) and non-metallurgical applications.

Certain ores have natural battery activity and, since these are relatively limited in supply, they tend to be used fairly exclusively for this purpose. The natural battery activity does not limit, however, the use of these ores in other applications.

For the most part, the non-metallurgical applications of manganese ores require high content of manganese and/or manganese dioxide. Lower grade ores can be upgraded and the natural battery activity increased, if necessary. The cost of upgrading is, generally, inversely proportional to the starting grade of the ore.

The North American non-metallurgical manganese market is dominated by a few companies which import natural ores directly from overseas producers. For any product, with the possible exception of agricultural manganese sulphate, the establishment of a new 'independent' supplier is likely to meet with resistance from the existing suppliers. An alternate route would be to secure a relationship with one of

these companies both for product development and for market access.

Due to the combination of two factors, namely the relatively easy use of metallurgical grade manganese ores for non-metallurgical purposes and the current more-than-adequate supply of metallurgical ores, there is no shortage of manganese for non-metallurgical applications. The long term supply of manganese ore for non-metallurgical applications, at grades considerably higher than those found at Woodstock, appears adequate to meet future expected demand.

The Woodstock, New Brunswick manganese deposits are low grade by any standard and, in the natural or untreated form, would find no market in non-metallurgical applications. Assuming that an economic, competitive processing method can be determined, there is some, limited potential in the Canadian market for agricultural manganese sulphate. The markets for manganese dioxide are diverse and most have stringent technical specifications. If it could be determined that manganese dioxide could be produced at grades approaching those presented in the section of this report headed PRODUCT SPECIFICATIONS, more detailed assessment of market potential may be undertaken.

APPENDIX I

TECHNICAL SPECIFICATIONS PROVIDED BY CANADA COLOURS AND CHEMICALS LIMITED

TECHNICAL DATA

Canada Colors and Chemicals Limited

MONTREAL TORONTO
HAMILTON ELMIRA
CALGARY EDMONTON
VANCOUVER

AMAPA AF

MnO_2	72%
Mn	48.9%
Fe	4.5%
Silicate	0.89%

Screen Analysis: 85-90% through 325 mesh

Source: American Minerals

Robertson & Associates

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TECHNICAL DATA

Canada Colors and Chemicals Limited

MONTREAL TORONTO
HAMILTON ELMIRA
CALGARY EDMONTON
VANCOUVER

GROOTE EYLANDT

(Manganese Ore)

TYPICAL ANALYSIS

Mn as MnO_2	82.5%
Fe as Fe_2O_3	3.8%
SiO_2	2.7%
Al_2O_3	3.3%

SCREEN ANALYSIS

Air Floated: 92% to 95% minus 325 mesh

Country of Origin: Australia

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Chemetals Incorporated

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Glen Burnie
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301-768-6600
TWX-710-861-0542

Manganous Oxide

CHEMETALS

Technical Bulletin

Manganous Oxide HP

MnO HP – Grade II

Formula

MnO

Specifications

MnO	99.4% min.
Fe	0.08% max.
SiO_2 Soluble	0.010% max.
Ba	0.004% max.
Insoluble in HCl	0.010% max.

Molecular Weight

70.94

Physical Appearance

Free-flowing green powder

Suggested Applications

Manganous Oxide HP is a high purity compound used in the production of ferrites, ceramics, welding rod fluxes and many manganese chemicals.

Packaging

50 and 100 lbs. net weight, multiwall paper bags
25 kgs. net weight, multiwall paper bags

Typical Chemical Analysis

MnO	99.7%
MnO_2	0.5%
Fe	0.01%
Insoluble in HCl	0.01%
SO_4	0.006%
CaO	0.005%
BaO	0.003%
Na_2O	0.01%
K_2O	0.005%

Typical Particle Size

+80 mesh	43%
−80 +200 mesh	54%
−200 +325 mesh	2%
−325 mesh	1%

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Manganous Oxide

CHEMETALS

Technical Bulletin

Manganous Oxide HPX	MnO HPX	
Formula	MnO	
Specifications	MnO	98.3% min.
	MnO_2	2% max.
	Fe	0.3% max.
	Ba	0.004% max.
	Insoluble in HCl	0.05% max.
Particle Size Specifications	– 10 microns	50% min.
	– 45 microns	99% min.
Molecular Weight	70.94	
Physical Appearance	Free-flowing green powder	
Suggested Applications	Manganese Oxide HPX is a versatile raw material for the preparation of manganese salts. It reacts readily with both mineral and organic acids.	
	Applications include production of ferrites, ceramics, manganese sulfate, manganese nitrate, manganese acetate, manganese phosphate, welding rod fluxes and many other manganese chemicals.	
Packaging	400 lbs. net weight, fiber drums	
Typical Chemical Analysis	MnO	98.5%
	MnO_2	1.8%
	Insoluble in HCl	0.04%
	Fe	0.15%
	CaO	0.005%
	BaO	0.003%
	$Na_2O + K_2O$	0.03%
	SO_4	0.006%
Typical Particle Size	– 10 microns	95%

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Manganous Manganic Oxide

CHEMETALS

Technical Bulletin

Manganous Manganic Oxide HPM

Formula	Mn_3O_4 HPM	
Specifications	Mn	70.5-72.5%
	MnO_2	38.0-42.0%
	Alkali and Alkaline Earths as Oxides	0.05% max.
	Soluble Si as SiO_2	0.015% max.
Particle Size Specifications	−325 mesh	85% min.
Molecular Weight	228.79	
Packaging	400 lb. fiber drums	
Typical Chemical Analysis	Mn	71.7%
	MnO_2	40.0%
	Fe	0.015%
	Soluble Si as SiO_2	0.01%
	Alkali and Alkaline Earths as Oxides	0.02%
Typical Particle Size	−325 mesh	94%

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Manganese Dioxide

CHEMETALS

Technical Bulletin

Manganese Dioxide

Battery Grade – Type M

Formula

MnO_2

Specifications

Mn	59.5% min.
MnO_2 (based on available O)	89% min.
O/Mn ratio	1.935% min.
Ni	0.001% max.
Co	0.001% max.
Cu	0.001% max.
Fe	0.1% max.
Na_2O	0.2% max.
K_2O	0.1% max.
CaO	0.2% max.
Insoluble in HCl	0.15% max.
H_2O	3% max.
pH	4.5 min.

Molecular Weight

86.92

Physical Properties

Particle Size: −325 mesh 76% min.
Bulk density: 1.4 ± 0.1 gr/cm³
Tap density: 1.8 ± 0.1 gr/cm³
Specific Surface: 80 m² per gram
Ion exchange capacity: 1.5 to 1.6 meq.
Zn^{+2} gr MnO_2
Kerosene Absorption: 40 ml/100 gr.
Crystalline structure: Gamma/rho

Packaging

50 kgs. net weight, multiwall paper bags

Typical Chemical Analysis

Mn	60%
MnO_2	90%
O/Mn ratio	1.95
Heavy Metals	0.002%
Ni	0.0005%
Co	0.0004%
Cu	0.0005%
Fe	0.005%
$Na_2O + K_2O$	0.2%
CaO	0.1%
Insoluble in HCl	0.02%
H_2O	2%
pH	5.5

The above material equals or exceeds U.S. Signal Corps. specifications S.C.L. 3175 for synthetic battery material. Type "M" is exclusively specified in U.S. Signal Corps. specifications (S.C.L. 6893B 16th June 1966) for "magnesium cells."

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Manganese Sulphate

CHEMETALS

Technical Bulletin

Manganese Sulphate	C. P. Grade	
Specifications	$MnSO_4 \cdot H_2O$	98% min.
	Mn	32% min.
	Free H_2O	0.4% max.
	Insoluble in H_2O	0.1% max.
	pH	7.5 max.
Density	6.7 gm/cm³	
Packaging	100 lbs. net weight, multiwall paper bags	
Typical Chemical Analysis	$MnSO_4 \cdot H_2O$	99%
	Mn	32.2%
	Free H_2O	0.03%
	Insoluble in H_2O	0.08%
	Insoluble in HCl	0.04%
	Fe	trace
	CaO	0.23%
	Alkalis	0.5%
	Zn	0.02%
	Heavy Metals	0.05%
	Cl	0.01%
Typical Particle Size	– 200 mesh	99%

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Manganese Chloride

CHEMETALS

Technical Bulletin

Manganese Chloride	Anhydrous Prills
Formula	$MnCl_2$
Specifications	Assay ($MnCl_2$) (dry basis) 97% min. Ni 0.009% max. H_2O 1.0% max.
Molecular Weight	125.84
Physical Properties	Light pink, anhydrous prills Melting point: 650°C Soluble in H_2O, Alcohol Insoluble in Ethyl ether, NH_3 Bulk density: 80 lbs./ft.
Suggested Applications	Magnesium and aluminum metallurgy Paper chemistry Paint dryers Manganese source in general chemical reactions
Packaging	400 lbs. net weight, steel drums
Typical Chemical Analysis	Assay (dry basis) 97% Mn 42% Fe 0.01% Insoluble in HCl 0.01% Alkali Chlorides 2% Ni 0.004% Cu 0.003% Pb 0.001% As 0.001% H_2O 0.5%
Typical Particle Size:	−6 + 16 mesh

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American Minerals

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(302) 652-3301
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Cable AMINPAR Newcastle, DE

IMINORE 3 MANGANESE DIOXIDE

Typical Chemistry

Mn	52.7%
MnO_2	81.2
Fe_2O_3	2.0
SiO_2	5.0
Al_2O_3	1.6

Screen Analysis

Airfloated: 92 to 95% minus 325 mesh

Shipping Point: Wilmington, Del.

December 5, 1985

Robertson & Associates

The
Coopers
& Lybrand
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Manganese Dioxide

CHEMETALS

Technical Bulletin

Manganese Dioxide C	Natural Ore – MnO_2 C	
Formula	MnO_2	
Specifications	Mn	49% min.
	MnO_2	70% min.
Particle Size Specifications	– 270 mesh	95% min.
Molecular Weight	86.94	
Suggested Applications	Brick Ceramics Chemicals Glass	
Packaging	50 or 100 lbs. net weight, multiwall paper bags	
Typical Chemical Analysis	Mn	51%
	MnO_2	75%
	Fe	3%
	Al_2O_3	6%
	SiO_2	3%
	BaO	0.2%
	Ni	0.06%
	Pb	trace
	S	0.015%
	Zn	0.05%
	Cu	0.04%
	P	0.1%
	K_2O	0.8%
	As	trace
	Na_2O	0.05%
Typical Particle Size	– 270 mesh	97%

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Manganous Oxide

CHEMETALS

Technical Bulletin

Manganous Oxide	Regular Grade	
Specifications	Mn	60% min.
Particle Size Specifications	– 200 mesh	75-95%
Suggested Applications	Animal feed	
Packaging	100 lbs. net weight, multiwall paper bags	
Typical Chemical Analysis	Mn	60%
	Fe	4%
	SiO_2	4%
	P	0.1%
	As	0.007%
	Pb	0.006%
	Cu + Ni + Zn	0.2%
	$K_2O + Na_2O$	1%
Typical Particle Size	– 200 mesh	80-90%

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APPENDIX II

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NON-METALLURGICAL MANGANESE MARKET STUDY

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Claim Map No. 5. Mineral Resources DivisionGOLD PROPOSAL